2008

Impact Of Construction On Freeway Traffic Operations

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IMPACT OF CONSTRUCTION ON FREEWAY TRAFFIC OPERATIONS

by

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B.S. University of Florida, 1993
M.S. University of Central Florida, 2005

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Civil,
Environmental, and Construction Engineering in the
College of Engineering and Computer Science
at the University of Central Florida
Orlando, Florida

Summer Term
2008

ABSTRACT

This study provides an insight into the impact of construction activities on traffic operations. Specifically, the topic of interest for this thesis is to study the impact of construction on traffic operations for construction projects on Interstate 4 from SR 434 to John Young Parkway, from SR 528 to SR 535, and from SR 482 to SR 528. These three projects were chosen because they were the only projects on Interstate 4 where both construction data and loop detector data were available for analysis.

The data was collected by examining the Florida Department of Transportation daily inspection reports which had detailed documentation of construction operations that took place. The following information was collected: date, type of construction work being performed, time, location, and direction of impact to the traveling public. These data points were cross-referenced to the loop detector stations and mile posts to collect the loop detector data and roadway geometric characteristics such as location of ramps, type of median, etc. The loop detector data (speed, volume, and occupancy) were collected and aggregated for the data analysis. The loop detector data were collected during construction, one year prior to construction, and one year after construction for comparison purposes.

Logistic regression analysis under the within-stratum matched sampling framework was conducted as an exploratory analysis to see if there was a difference on the traffic impacts with and without construction. This was done by matching the variables to ensure that there were no other differences impacting the traffic operations. Logistic regression proved there was a difference in the traffic operations with and without the presence of construction.

The simple model results demonstrated that speed was reduced, occupancy was increased, and volume decreased during construction. After construction, the speed and volume increased and the occupancy decreased.

Linear regression and analysis of covariance were used to quantify the impact of the various construction activities on the speed, occupancy and volume. Linear regression and analysis of covariance were used to understand the impacts from the presence of roadway geometrics on freeway traffic operations during construction. Logistic regression controls the geometrics, linear regression and analysis of covariance demonstrated how the geometrics impacted the construction effects. The geometric characteristics of each area were included in this analysis. This thesis investigates construction activities and roadway geometric parameters that impact traffic freeway operations (speed, volume, and occupancy) before, during, and after construction.

This research showed the impact of different types of construction operations in a highway construction widening project. This research demonstrated that construction activities have a significant impact on speed, volume, and occupancy. Different types of construction activities have more of an impact than other activities. Paving had the highest adverse impact. Agencies writing construction contracts should prohibit paving during the most highly congested times. For example, in Orlando, Florida on Interstate 4, agencies should prohibit night paving during the peak holiday seasons (such as Thanksgiving, spring breaks, Christmas, etc.) around the tourist attractions during closing times, during the peak morning hours, and during the closing times of high attendance activities, such as Halloween Horror Nights at Universal Studios when high attendance is anticipated at the theme parks. Roadway geometrics also impact the traffic operations differently, before, during, and after construction and differently during various times of the day. The information of improved roadway geometrics and faster traffic flow can be used at open houses for upcoming projects where there are many people opposed to construction projects to show how the roadway construction projects actually increase traffic flow, helping everyone to get to their destinations much faster. The impact of the traffic delays in the congested areas, such as the tourist areas on Interstate 4 during the peak traffic times could be quantified to calculate delay costs to the roadway users.

ACKNOWLEDGMENTS

The author would like to thank the following people:

- Dr. Haitham Al–Deek for his support and advice.
- Anurag Pande for his generous assistance with running Java script and SAS.
- Yueliang Zuo for writing the Java script that enabled the loop data extraction from the data warehouse and Ravi Chilakamarri for tweaking it.

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CHAPTER 1 INTRODUCTION

1.1 Background

Roadway improvement projects always impact traffic operations while construction work is being performed. The general impact of construction has been studied, but not specifically by the type of construction work taking place (Kremer et al. (2004), Aghazadeh et al. (2004), and Chien (2000)). Examination of this aspect is important. Perhaps those construction activities which impact the traffic most adversely can be limited to the number of days allowed by the contractor in the construction contract. This information can also be utilized on days when heavy traffic flow is anticipated from special events or peak tourist season; i.e. those activities which impact the traffic the most could be prohibited before and after the special event until the traffic clears. This information can be used at public information meetings where citizens have concerns about the impacts of construction projects to the traffic flow. According to a report published by FHWA (2003), "lack of communication is often cited as a key cause of frustration to the traveling public."

As of early spring 2004, the Orlando, Florida area (Volusia, Seminole, Orange, and Osceola Counties) Interstate 4 (I–4) had 74.7 miles of roadway, and with 44.7 miles of it being under construction funded by the Florida Department of Transportation (FDOT). Only 30 miles of this roadway in Central Florida were not under construction. Interstate 4 is the primary east-west artery going through Orlando.

1.2 Research Objective

The purpose of this study is to investigate the impacts of construction and the roadway geometric characteristics on freeway traffic operations before construction, during construction, and after construction. This study examines the hypothesis that different types of construction activities impact the speed, occupancy, and volume differently and that the impacts roadway geometrics to the speed, occupancy, and volume are also impacted by the roadway construction. The chief intention was to determine the impact of construction operations on the speed, occupancy, and volume. These construction projects investigated were typical to any interstate widening project; therefore this study can be applied to most interstate roadway widening projects. Many of the interstates around the nation were constructed in the 1960s, were widened in the 1980s, and now many of the existing interstates are being widened again because of the population growth of cities.

1.3 Solution Approach

1.3.1 Collection of Data

The data were collected from the daily construction reports that were completed by the construction compliance inspectors who were working as agents for the Florida Department of Transportation (FDOT) to ensure that the construction specifications were being followed and to document the progress of the work of the contractors building these projects. There were three separate Design–Build construction projects that were investigated which will be described in more detail in a following section. The information collected for this analysis included the day of work, type of work, time of work, direction of I–4 where work was performed, and work performed. The loop detector data, the occupancy, speed, and volume data, were collected. The locations for the work were cross–referenced to the station for the vehicle loop detectors. Although this task was time consuming, the results were that the databases created were as precise as possible.

1.3.2 Organization of the Data

After the data was collected it was organized into one concise list of all work. The days, times, and locations were replicated for the same day of the week the previous year and the following year for comparison purposes.

1.3.3 Pre–Analysis and Data Exploration

The data had to be run with a java script to extract the loop data (speeds, occupancies, and volumes) and then aggregated by use of SAS to obtain 15 minute average speeds and traffic volume (SAS Institute, 2001) during construction, the year prior to construction, and the year after construction.

1.3.4 Analysis Method

The analysis methods chosen were unique in that they involved a tremendous amount of information on several thousand data entries. Based upon the thorough literature review conducted, it was evident that studies such as this are rare (Rister et al. (2002), Al–Kaisy and Hall (2000), and Maze et al. (1999)). In this thesis models were built depending on variables found to be significant and in a way that has not been previously studied.

In order to achieve the objective, the problem was approached in reverse. The locations, time of the day, and day of the week during construction were controlled and the traffic conditions during construction were compared to the same location, time of day, and day of the week without construction activities.

Logistic regression analysis under the within stratum matched sampling framework was conducted as an exploratory analysis to see if there was a difference on the traffic impacts with and without construction. This was done by matching the variables to ensure that there were no other differences impacting the traffic operations. Logistic regression proved there was a difference with and without the presence of construction.

Linear regression and analysis of covariance (ANCOVA) was used to quantify the impact of the construction activities and the geometric conditions of Interstate 4 on speed, volume, and occupancy utilizing linear models with categorical and continuous independent variables. Linear regression and ANCOVA were used to understand the presence of geometrics before, during, and after construction activities. The before, during, and after models were then compared for similarities and differences for impacts from construction activities and determined how the presence of construction and roadway improvements changed the impacts from the geometric roadway conditions.

1.3.5 Reporting the Results

The results from the various models built were collected and the model interpretations are stated herein.

1.4 Thesis Organization

Chapter Two provides a detailed review of other similar construction investigations that are slightly different than the research presented in this study. The third chapter provides information on the data collection. Chapter Four describes the data exploration and the use of matched case logistic regression analysis. Chapter Five describes the development of the models for the speed, occupancy and volume given the impacts of construction and the roadway geometrics through linear regression and analysis of covariance (ANCOVA). The last chapter contains the conclusion from this research and how the findings can be used to determine traffic impacts from construction to volume, speed, and occupancy.

CHAPTER 2 LITERATURE REVIEW

2.1 General

This chapter reviews the literature collected on the impact of construction of work zones on several traffic features. The objective of the literature review was to identify the possible approaches to study the impact of construction activities on congestion.

2.2 Previous Research

In 1998, FHWA produced a report entitled *Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations.* This report stated that work zones were responsible for 24% of non-recurring congestion, which is equivalent to 482 million vehicle hours of delay per year (FHWA, 2004). Non-recurring congestion can be mostly attributed to incidents (any activity which impedes the traffic flow), inclement weather, work zones and breakdowns. This report stated that a tool should be developed to quantify effects in work zones. As a result, a tool called QuickZone was produced to assist State and local construction, operations, and construction planning contractors. QuickZone has several capabilities, including:

- Quantifying work zone delay due to lane closures.
- Estimating delays of various maintenance of traffic phasing.
- Comparing the construction operations cost to the delay cost experienced by the motorists from the construction.

In 2002, FHWA sponsored a study of 13 states to determine the capacity loss on the interstates due to construction. The 13 states can be seen in Figure 2-1. The 13 states account for 24.5% of the total interstate miles in the United States. (FHWA, 2003) The work zones in these states accounted for 12.8% of the US interstate miles. For the work zones studied, that was a lost capacity of 15 million vehicles hours per day; extrapolating to the total nation, it was a capacity loss of 60 million vehicles hours per day on the national interstate system. See Figures 2–1 and 2–2. Figure 2–1 shows that the study was representative of projects across the nation.

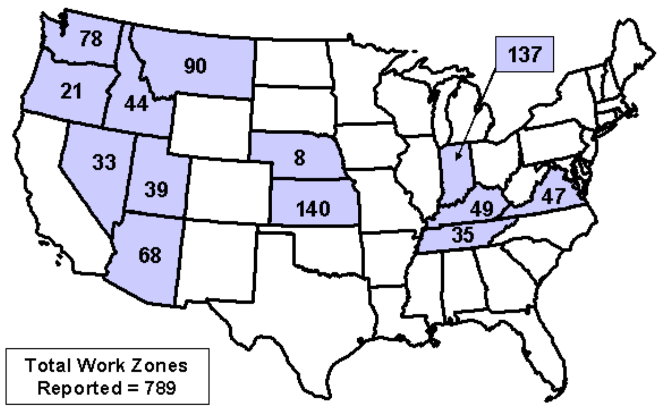

Figure 2-1 States in the study

The pie graph in Figure 2–2 indicates the type of work taking place in the work zones. It is interesting to note that in Figure 2–2, the largest segment was bridge construction. In Figure 3–2, the breakdown of the data points obtained for this thesis, the largest category was bridge construction (including the categories of bridge demolition, pile driving and half of the concrete pours as described in 3.2.1).

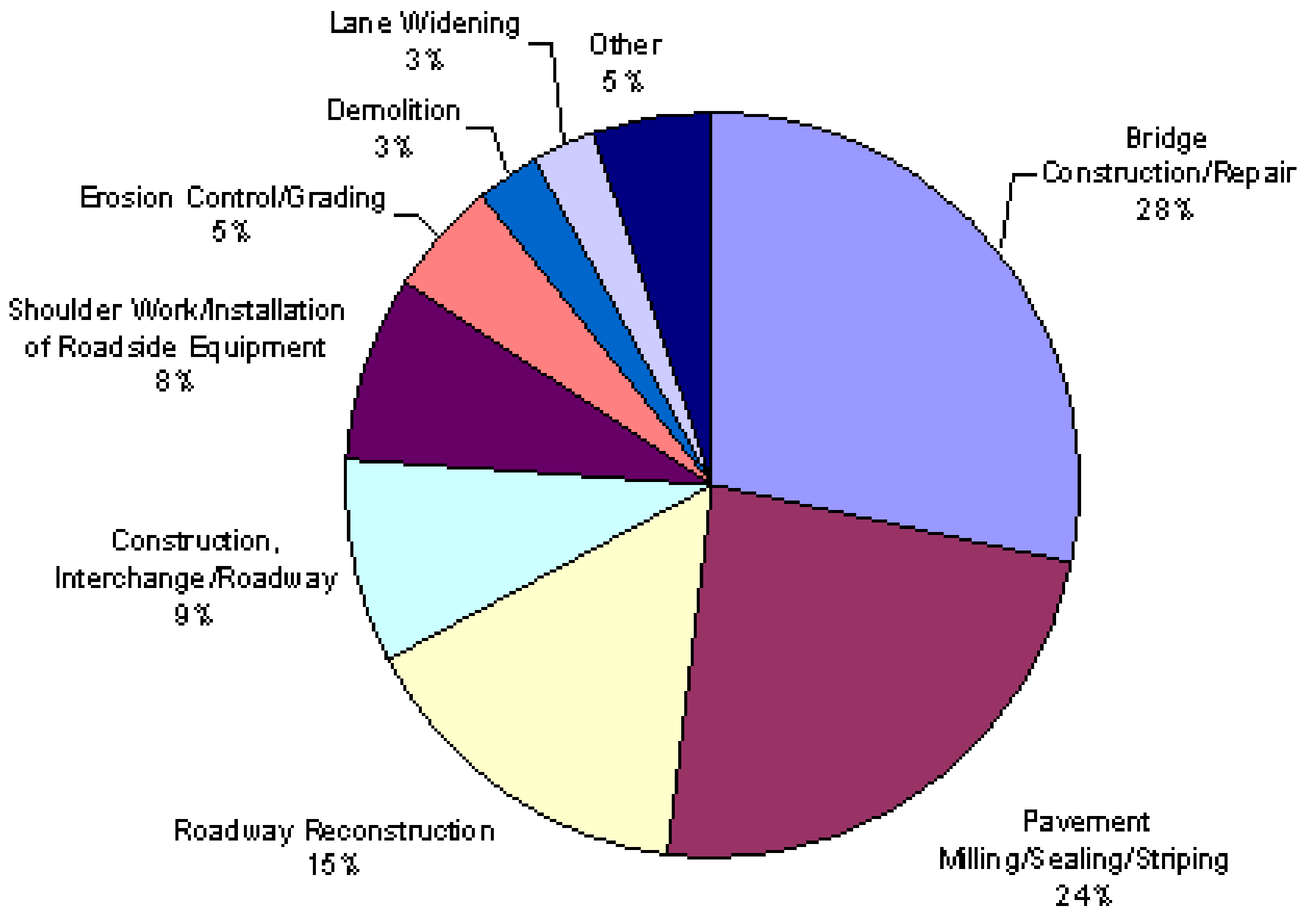

Figure 2-2 Types of construction in the FHWA study

In 2001, a study was conducted to evaluate two alternative phasing plans for Interstate 80 near Saddle Brook, NJ (Kremer, et al., 2001). This was for a road widening project. The first alternative reduced the lanes to 11' lanes and had shoulders for disabled vehicles. The construction was to be completed in 3 phases. The second alternative was submitted by the contractor as an alternative maintenance of traffic where all the work would be done in one phase; however there would be no shoulders for disabled vehicles. The analysis consisted of a four step process; targeting the scope of investigation, data collection, traffic engineering analysis, and investigation. The traffic was simulated using INTEGRATION operational model platform. This study was unique in that NJDOT was able to do a one week trial in each traffic phase on the actual roadway. Both the analysis and the actual trial phase showed that the alternative plan with no shoulders caused the most delay to the motorists.

The Louisiana Transportation Research Center (Aghazadeh, 2003) produced a report to evaluate the accuracy of a program for Life–Cycle Cost Analysis (LCC). This was produced by FHWA to predict user costs from construction and maintenance work on the roadways. This report was produced for two construction zones on I–10 in LaPlace and Lake Charles, both in Louisiana. The goal of the paper was to prove the accuracy of the model inputs, comparing the model outputs to the actual delays (the actual delay was field tested and compared to the model output), and to perform a sensitivity analysis for the model's output for user delay costs compared to input errors. The conclusion was that the actual traffic was less than the model predicted. The model overestimated the delay time, and the lack of data during the actual delay limited the output comparison for one of the construction zones.

Chien (2000) used CORSIM to estimate work zone delays for I–80 in New Jersey. The model investigated volumes, capacity, queuing delays, flow rates, work zone capacities, average speeds, amongst other variables. His report found that the CORSIM model underestimated the overall delays and that realistic output depended on the accuracy of the delay curve produced by CORSIM.

The University of Kentucky (Rister, 2002) investigated several methods “quantifying/ calculating” delay costs in work zones. This report looked at 3 delay software programs, Quick Zone, QUEWZ–98, and FHWA’s Demonstration Project 115 (a program that calculates the life–cycle cost analysis in pavement design). FHWA’s Demonstration Project was found to be most user-friendly and was more suited to find the quantity of delay and queue lengths in work zones.

Kazmi, et al. (2001) evaluated the freeway for the Bridge of Americas Port of Entry. This is a junction of several freeways I–110, I–10, Border Highway, and US 545. There is an international border crossing which presents another challenge with the congestion in addition to the high percentage of vehicular traffic which prohibits certain vehicular movement from occurring. This study was done jointly with Texas Department of Transportation (TxDOT), City of El Paso, El Paso Metropolitan Planning Organization, US Customs, the trucking industry, and the Maquiladora (twin plant industry). CORSIM was used to evaluate the future construction impacts as well as the future traffic operations characteristics. CORSIM was able to handle the complexity of the interchange layout and the ease for preparing graphics for public information meetings. The outcome of the study was utilized for the presentation to TxDOT, FHWA and the affected entities for their approval of the construction of the ramps. Kazmi et al. (2001) used CORSIM for construction modeling and looked at construction as a whole, rather than individual activities.

Flack, et al. (2002) presented a modeling process for the construction phasing and daily operational analysis for the purpose of recommending specific alternatives during construction for the I–235 in Des Moines, IA. The Massachusetts Institute of Technology developed a microscopic traffic simulator MITSIM which was used for the analysis. Flak et al. (2001) used MITSIM for construction modeling and looked at construction as a whole, rather than individual activities. This study looks at construction phasing, whereas this thesis looks at construction activities and their impacts.

Freeway capacity in long term lane closures in work zones was studied by Al–Kaisy, et al. (2000) in Ontario, Canada on the Gardiner Expressway in Toronto. The findings indicated a difference in the freeway capacity in work zones. The variables studied included temporal variation (which was thought to relate to driver characteristics), grade, day of week, and weather conditions. The conclusion was that data needed to be collected longer and more extensively than the 4 days or 53 hours for better predictions.

Al–Kaisy and Hall (2001) also evaluated the effect of driver population factor on the capacities of long term freeway construction zones on this same highway as mentioned in the preceding paragraph. This investigation compared mean capacity flows during different times of day and day of the week to predict the effect that commuters versus non-commuters have on the roadways. This study found a significant difference with the driver population factor. Using 1.0 as a basis for commuter traffic, it found that the afternoons produced a population driver factor of 0.93 and a 0.84 driver population factor was generated for weekends. The non-commuters were also found responsible for the weekend reduced capacity compared to the weekday capacity. One direction of traffic had a 12% capacity reduction, whereas the other direction had a 17% reduction. The information generated was considered to be conservative since the data was collected in April and early May when there was a higher proportion of tourists. These findings were consistent with the findings from other studies.

Another study by Al–Kaisy and Hall (2000) evaluated the effect of darkness on freeway capacity for work zones; the same work zones as mentioned in the preceding two paragraphs. At two construction zones, the data were collected for the PM peak periods before and after the daylight savings change from daylight savings to standard time using video records at 5 minute intervals. Heavy vehicles were correlated to passenger car equivalents with the Highway Capacity Manual factors. The results concluded that lighting had different impacts at the two sites; at one site the capacity declined by 7.5% whereas the other declined by 3.25%. Al–Kaisy and Hall (2000) found that this difference can be attributed to the difference in grades at the two sites and concluded that the "compound effect of two or more variables on freeway capacity was interactive rather than additive."

Jiang and Adeli (2004) developed a model to predict work zone capacity and traffic delays. A model was developed for different variables such as work zone layout, number of lanes, work intensity, and time of day. The model was object oriented. It was implemented into Intellizone, an interactive software system that used Microsoft Foundation Classes, and incorporated a hierarchy of multiple specialized frameworks. This worked on pattern recognition and neural network models, which incorporated different work zone characteristics to evaluate the capacity to provide a new generation of advanced systems for more effective management of work zone traffic.

Benekohal, et al. (2003) conducted a study for developing a new method for finding capacity, speed reduction, delay, queue length, and user costs. Operating speed was used for speed reductions due to the construction. Speed flow curves were used to find capacity. The Illinois Department of Transportation (IDOT) requires traffic back up analysis to be performed in work zones to assist with the determination of the innovative contracting methods such as lane rentals and incentives/disincentives. Capacity determination was based on the HCM and queue length and delays were based on QUEWZ, Quick Zone, and HCM. QUEWZ is a computer tool/program for estimating traffic impacts and road user costs in short term freeway construction zones utilized in scheduling freeway construction zone activities.. Road user costs were determined by QUEWZ and spreadsheets. Fourteen work zones were analyzed for headway and traffic flow data and compared to results from FRESIM, QUEWZ, and Quickzone. According to IDOT's findings, the results were as follows:

1. "QUEWZ overestimated the capacity and average speed, but underestimated the average queue length."
2. "Speeds computed in FRESIM were comparable to the average speeds from the field data when there was no queuing at the work zones. However, when there was queuing, FRESIM overestimated the speed. The queue lengths obtained from FRESIM were shorter than the field values in half of the cases and longer in the other half of the cases."
3. "The queue lengths from QuickZone did not match the field data and generally QuickZone underestimated the queue lengths. QuickZone consistently underestimated the total delay observed in the field. When demand is less than capacity QuickZone does not return any user delay because it does not consider the delay due to slower speeds in the work zones.

This study looked at construction as a whole, whereas this thesis looks at individual construction activities.

The IMSA (International Municipal Signal Association – 2003) Journal discussed four tools used for looking at the operations of work zones; Work Zone Delay Impact Analysis Spreadsheet, Expert System Software Program, Cost/Alternative Analysis Spreadsheet, and a Detailed Simulation Model. Quick Zone was fully examined in this article. It was developed by Mitreck System utilizing Excel and can be used for urban and interurban analysis. Quick Zone has the capability to quantify corridor delay from construction capacity delay, identifies the impacts of alternative phasing plans, and can do an analysis with the trade off between construction and delay costs. Quick Zone has the ability to take into account alternative phasing, gauge the impact of delay minimization options, and incorporates innovative contracting methods such as lane rentals and incentive/disincentive alternatives.

The Ohio DOT performed a study to evaluate if the traffic simulation models available for use could be calibrated to accurately predict queue length and delay time for when the ODOT required traffic operations predictions in work zones (Schnell, et al., 2002). In this study, four work zones on multilane freeways were used for data collection via traffic flow video records using Mobilizer–PC software package. The traffic simulation and prediction tools analyzed by Schnell et al. were Highway Capacity Software (HCS), Synchro, CORSIM, NetSim, and the microscopic model QueWZ92. Simulation models were developed for the work zones, the generated queue lengths and delay times were compared with the data obtained from the video records. The results concluded that the simulation packages underestimated the queue lengths on the actual roadway and it was also determined that the QueWZ92 generated the most accurate predictions compared to the other microscopic packages.

Jiang (2001) conducted a study for accurate prediction of traffic delays on Indiana freeway work zones. Several equations for various traffic operation delays were developed. It was found that when determining traffic delays, the queue discharging rates should be utilized instead of the work zone capacity since the queue discharge rates were less than the work zone capacity. Individual vehicle queue equations were generated for the estimation of queue lengths, time needed for queues to dissipate, and average and total traffic queue delays. The information generated was used for the display on the dynamic message boards on the interstates for real time travel information.

Jiang (1999) also examined traffic capacity, speed and queue discharge rates on Indiana's interstates. This study found that traffic in work zones had low vehicle speeds and variable traffic flow rates. The traffic flow could be generalized as sharp speed drop when entering the work zone, then lower speeds, and finally changing traffic flow rates. The results showed the mean queue rates were lower than the work zone capacities on Indiana's freeways. There were times that the individual queue rates were higher than the work zone capacities. This showed Jiang that the work zone capacity values should not be used in lieu of the queue discharging rates for estimation of delays and user costs. During the times when the roadways were generally uncongested, the speed limit remained the same (55mph), whereas during peak times, the speed dropped 31.6% – 56.1% from the normal speeds. This study concluded that the prediction of traffic congestion, traffic delays, and user costs can be generated by input from work zone capacity, queue discharging rates, and vehicle speed.

Vadakpat and Dixon (1999) calibrated a model using CORSIM to forecast delays in work zones on North Carolina interstates. The incident specification in CORSIM along with a lane blockage was used to replicate a lane closure on a four lane highway (two lanes in each direction). The report showed that rubber necking at a 50% factor and the default car following sensitivity factor can duplicate the driver and vehicle actions in work zones. The outcome concluded that CORSIM can be used for traffic modeling.

CORSIM (CORridor SIMulation) is a traffic simulation tool for city streets, freeways and basic traffic operations, which was developed in the 1970's through the Federal Highway Administration (FHWA) (University of Florida, 2008). CORSIM has 2 models NETSIM for street networks and FRESIM for freeway modeling. The software tool has the ability for the traffic stream to have nine types of vehicles, reserved carpool or bus lanes, warning signs can be simulated, and incidents can occur with the type of incident being specified. The output calculated includes: emission levels, fuel consumption, traffic volume, delay time, stopped delay, travel time, queue time, queue length, and speed.

Benekohal and El–Zohairy (1999) investigated the amount of delay at truck weigh in stations along interstates to determine the effectiveness and safety of the Automatic Vehicle Identification Weigh In Motion systems in Illinois. This study found that the average delay was 4.95 minutes per truck and varied from 3.56 minutes to 6.95 minutes per truck. The maximum delay varied from 8.69 to 137.62 minutes. Models used to predict the numbers of conflicts were developed. Benekohal and El-Zohairy studied and modeled delays to traffic, whereas this thesis studies and models traffic operations.

Soares and Najafi (1999) conducted a study to determine the user costs of work zone delay. The report states those management plans were essential in reducing road user costs, and includes working with the government agency, roadway users and the contractors. At the time the report was written there was no computer software available that incorporated all variables related to work zone delay costs. The largest complication in determining the costs was the quantification of travel time. This study found that the costs associated with delay were $11.12 for cars and ranged from $12.61 – $30.26 for trucks per hour.

Sisiopiku and Lyles. (1999) studied the speed patterns for highway work zones in Michigan. The calculations were a comparison of mean speeds during and after construction. In all the sites studied, the average speed was always higher than the posted speed. For 60 mph work zones, the average speeds ranged from 56.1 mph to 74.4 mph. Sites where the speed was reduced from 70 mph to 60 mph to 50 mph had average speeds ranging from 57.3 mph to 64.0 mph; the motorist speed reduction was typically 55%–75% of the lower posted speed. ANOVA was used to determine the statistical difference with the various work zone differences such as type of lane closure (barrier walls, cones, or drums), workers present, number of lanes open to traffic, and speed. The outcome showed that all the variables had significant effects (0.05 or better) on the speed.

Prevedouros and Wang (1999) studied the various roadway simulation models. INTEGRATION's issues are with complex signalization modeling and lane changes. CORSIM is similar to FRESIM and generated lower simulated speeds for vehicles merging on to interstates. CORSIM needed adjustments for volumes. WATsim was able to replicate volumes with fewer modifications. The best results were seen with NETSIM for signalized intersections simulation and INTEGRATION for freeway simulation.

Jiang (1999) explored the estimation of user costs in Indiana work zones. QUEWZ is a software available for the estimation, however, it was produced by Texas Transportation Institute based on their construction costs. This study generated figures specific to Indiana's environment and resources. Work zone user costs were impacted by traffic flow rates, vehicle speeds, and work zone lengths. Work zone traffic delay costs of vehicle queues was the largest percentage of the total user costs for congested conditions. Studies on I–70 and I–65 work zones showed that the excess running costs caused by speed changes was negative, therefore signifying that reduced speeds in work zones reduced the vehicle running costs. This study also showed that for long work zones, the reduced speed delay cost and excess running costs due to speed changes were a large percentage for total excess user costs.

Delwar and Papagiannakis. (1999) compared user delay costs for resurfacing activities. For 2 lane highways with an AADT of 13,500, lane closures of 5 – 10 miles, the delay costs were found to be 13–32% higher than for 1 mile lane closures. This can be attributed to the time it takes to accelerate and decelerate from highway speed. For 4 – 6 lane highways, delay costs for 5–10 miles lane closures were 250% – 560% higher than for 1 mile lane closures. The user delay costs can also be related to the size of the roadway. For low volume and short lane closures on 2 lane highways, the delay costs were higher than the delay costs for 4 – 6 lane highways.

Rilett et al. (1999) compared TRANSIMS to CORSIM. This study was conducted in Houston, TX and found that both functioned equally with the simulation of the base line data. With TRANSIMS, the optimal calibration parameter was different than indicated in the user's manual. TRANSIMS was easier to calibrate than CORSIM. The mean travel time output was generally 20% higher than indicated by CORSIM. The actual travel times were in between the values generated by both programs and the link and corridor travel time were less than the observed travel times.

Gardes et al. (1999) presented a paper on the application of Paramics for traffic model simulation. It assessed the model that developed and evaluated the various construction improvement strategies for I–680 in the San Francisco Bay Area. Paramics has 5 software modules: modeller (core simulation and visualization), processor (configuration tool for network simulations), analyzer (produces reports), programmer, and monitor (interface between emissions and the road network). The paper describes the calibration, application and results of the modeling. Gardes et al. (1999) studied developed construction improvement strategies, whereas this thesis studies and models traffic operations.

2.3 Conclusions

The literature review found models for investigating the impact of construction have been developed; however, literature on the impact of different types of construction on traffic operations was limited. Since there has not been much research on the different types of construction and the impact they have on traffic, this study will focus on developing models to deal with categorization of construction activities and their various impacts they have on freeway traffic operations.

CHAPTER 3 DATA COLLECTION

3.1 Background of Construction Projects

The three projects selected for this study were Design–Build projects that began core construction work in August 2001 and were completed in July 2004 on Interstate 4 (I–4) in Orlando, Florida. The projects were under 3 separate Design–Build construction contracts administered by the Florida Department of Transportation. These 3 projects involved the addition of auxiliary lanes to increase the traffic flow along the interstate and were typical of any interstate widening project. Work on the interstate included adding lanes to connect off ramp to off ramp, drainage improvements, additional ponds, addition of guardrail, widening 14 bridges, reconstruction of the median, an upgrade of the intelligent transportation system (ITS) items (placement of dynamic message boards, installing conduits, fiber optic splices, testing the fiber optic lines, and working in and replacing the hub cabinets along the roadway and remote traffic management system upgrade), lighting, and drainage modifications. The interchanges on I–4 were not reconstructed. These three projects were selected for data analysis in this thesis because of the availability of the construction data and the availability of the loop detector data during construction, the year prior to construction, and the year after construction. This data provided the traffic information for analysis. Figure 3–1 shows a map of the area. Table 3–1 is a brief description of the projects. Appendix C shows aerial photos of the area during construction. Section 3.2.1 describes the different types of work.

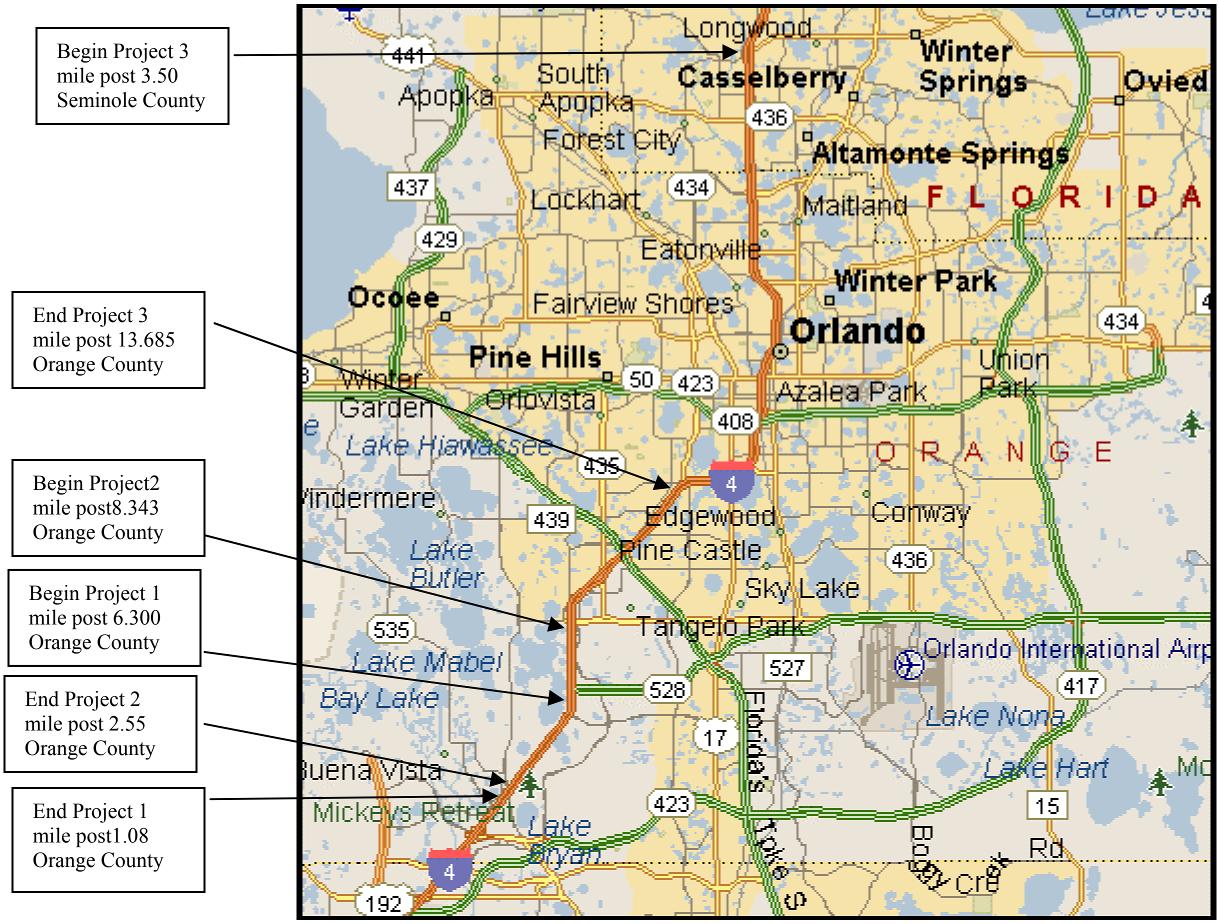

Figure 3-3 Map of area studied

Source: FDOT (2006), Orlando, Florida

Interstate 4 is the primary north and south artery in greater Orlando. With the significant growth in the Orlando area and increased congestion on the roadway, it is evident why the roadway was under construction. I-4 originally was primarily a route for traffic traveling from the East coast of Florida to the West coast; however, over the years with the increasing population, the majority of the traffic on I-4 is commuters on short trips. During peak hours the congestion has increased dramatically over the years throughout the greater Orlando area.

The first project went from SR 536 to SR 528. It was constructed by Jones Brothers in 501 calendar days for $14 million and was approximately 5 miles in length. It included the construction of a new concrete bridge, I–4 over Central Florida Parkway, asphalt roadway widening, drainage improvements, sign improvements, demolition and removal of an existing rest area facility, guardrail installation, and installation of an intelligent transportation system (ITS) amongst the other typical items constructed on interstate widening projects. The work began on August 23, 2001 and was completed on January 2, 2003. The project limits began at the I–4 and SR 528 interchange (mile post 6.300 as defined by FDOT, exit # 29, as shown on the interstate signing) and ended at the I–4 and SR 536 interchange. (mile post 1.08, exit # 26). See Figure C–14.

The second project evaluated was from SR 535 to SR 482. It was constructed by APAC Construction in 384 days for $5.1 million and was approximately 6 miles in length. This project included roadway widening, drainage improvements, signing improvements, guardrail installation and ITS improvements. The work began on June 2, 2002 and was finished on June 21, 2003. The project limits began at the I–4 and SR 428 interchange (mile post 8.343, exit # 29) and ended at the I–4 and SR 535 interchange (milepost 2.550, exit # 27). There was a slight overlap with the first project due to the addition of guardrail to the contract; however the time frames of the work that occurred in both project limits did not overlap. See Figures C–9 through C–13.

The third project was from SR 423 (John Young Parkway) to SR 434. It was constructed by Hubbard Construction in 953 days for $59 million and was approximately 14 miles in length.

The work began on October 22, 2001 and finished on March 26, 2004. The project limits began at the I–4 and SR 434 interchange (mile post 3.500, exit # 49) and ended at the I–4 and SR 423 (John Young Parkway) interchange (mile post 13.685, exit # 32). This project involved roadway widening and rehabilitation (concrete and asphalt widening) including modifying 13 bridges through downtown Orlando, drainage improvements, signing improvements, guardrail installation, and ITS improvements. See Figures C–1 through C–8.

Table 3-1 Summary of projects studied

Project # (as referenced in Appendix C)	**Interstate 4 Project Description**	**Construction Days**	**Contract Price**	**Dates of Construction**
1	SR 536 to SR 528 – It included the construction of a new concrete bridge, I–4 over Central Florida Parkway, asphalt roadway widening, drainage improvements, sign improvements, demolition and removal of an existing rest area facility, and ITS installation. 5 miles in length.	501	$14 M	August 23, 2001 to January 2, 2003
2	SR 535 to SR 482 – This project included roadway widening, drainage improvements, signing, ITS installation, and guardrail installation. 6 miles in length.	384	$5.1 M	June 2, 2002 to June 21, 2003
3	SR 423 to SR 434. This project involved roadway widening and rehabilitation (concrete and asphalt widening) including modifying 13 bridges through downtown Orlando, drainage improvements, ITS installation, and guardrail. 10 miles in length.	953	$59 M	October 22, 2001 to March 26, 2004

3.2 Summary of Data Collection

The information from the daily inspection reports for all three construction projects was collected from the Florida Department of Transportation and organized into one concise list of all work. The daily reports of construction are documents created by the construction, engineering, and inspection staff detailing the construction work taking place each day and other pertinent information. The data collected for this thesis includes the following:

- A case number was assigned for each type of work for each day and each time segment of the days of work. See section 3.2.1.
- Date the construction activity took place.
- Day corresponding to the day of the week that the data were collected (Monday, Tuesday, etc).
- Direction of impact for the traveling public – (eastbound or westbound).
- Time range the work was performed – Each range represents a 1 ½ hour segment, 10:30 pm–2:00 am, 12:30 am–2:00 am, 2:30 am–4:00 am, 4:30 am–6:00 am, 7:30 am–9:00 am, 10:30 am–12:00 pm, and 1:30 pm–3:00 pm.
- Type of work – 13 different types of construction work performed (See Table 3-2, Figure 3-3, and Section 3.2.1).
- Code for work – A numerical value assigned to the corresponding type of work.
- Location of the work taking place – Station as shown in the plans, bridge, or pond location used to correlate to the loop detector data. This information was utilized to determine which loop detector data to collect.

Table 3–2 represents a small segment of all the data collected. Figure A–1 is a blank daily report of construction from where the data were collected.

Table 3-2 Sample of summary of data collected

Date	Day	Direction	Time–Range	Loop Detector Station	Type Of Work	Code For Work	Location
8/9/2002	Friday	W	22:30–24:00	35	Bridgework	12	Kaley
8/9/2002	Friday	W	0:30–2:00	35	Bridgework	12	Kaley
8/9/2002	Friday	W	2:30–4:00	35	Bridgework	12	Kaley
8/9/2002	Friday	W	4:00–6:00	35	Bridgework	12	Kaley
8/9/2002	Friday	E	22:30–24:00	35	Bridgework	12	Kaley
8/9/2002	Friday	E	0:30–2:00	35	Bridgework	12	Kaley
8/9/2002	Friday	E	2:30–4:00	35	Bridgework	12	Kaley
8/9/2002	Friday	E	4:30–6:00	35	Bridgework	12	Kaley
8/9/2002	Friday	W	7:30–9:00	33	Bridgework	12	OBT
8/9/2002	Friday	W	10:30–12:00	33	Bridgework	12	OBT
8/9/2002	Friday	W	13:30–15:00	33	Bridgework	12	OBT
8/9/2002	Friday	W	7:30–9:00	34	Bridgework	12	W. Moreland
8/9/2002	Friday	W	10:30–12:00	34	Bridgework	12	W. Moreland
8/9/2002	Friday	W	13:30–15:00	34	Bridgework	12	W. Moreland
8/10/2002	Saturday	W	22:30–24:00	49	Install loops	1	417
8/11/2002	Sunday	W	0:30–2:00	49	Install loops	1	417
8/11/2002	Sunday	W	2:30–4:00	49	Install loops	1	417
8/11/2002	Sunday	W	4:30–6:00	49	Install loops	1	417
8/12/2002	Monday	W	7:30–9:00	33	Bridgework	12	OBT
8/12/2002	Monday	W	10:30–12:00	33	Bridgework	12	OBT
8/12/2002	Monday	W	13:30–15:00	33	Bridgework	12	OBT
8/12/2002	Monday	E	7:30–9:00	38	Pile driving	7	South Street
8/12/2002	Monday	E	10:30–12:00	38	Pile driving	7	South Street
8/12/2002	Monday	E	13:30–15:00	38	Pile driving	7	South Street

The station, pond location, or bridge location was correlated to the locations of the loop detectors. See Table B–1 and Figures B–1 to B–8 for loop detector locations in a table format and maps of loop detector locations. If work took place across several stations, then the downstream loop was the area in which the data were collected where the total impact would be shown in the loop detector readings. If several types of work were taking place at the same location, then the construction data was not collected because the overlapping effect on the operations becomes difficult to quantify the effect of each type of work activity. The activities that took place simultaneously were excluded from this thesis. The data was correlated to the year prior to construction and the year after construction for the same day of the week and same time for this analysis.

The Florida Department of Transportation collects the loop detector data on Interstate 4. It is transmitted back to the Regional Traffic Management Center instantaneously. The loop detector data includes the speed, volume, and occupancy data. The loop detector data were collected from the UCF data warehouse. (Chandra and Al-Deek 2004). The loop detector data information was collected and used in this study.

3.2.1 Types of Work Evaluated

There were 15 types different types of work collected for analysis. Table 3–3 and Figure 3–2 show the frequency of each of the different types of work and Table 3-4 is a summary of the types of construction work and the details outlined below.

Table 3-3 Summary of types of work

Code for Work	Type of Work	Frequency	Percent	Cumulative Frequency
1	Installation of loops	39	0.54%	39
2	Excavating ponds	1159	15.93%	1198
3	Paving	1070	14.71%	2268
4	Stabilization and limerock base	1337	18.38%	3605
5	Digging ditches and earthwork	494	6.79%	4099
6	Guardrail	373	5.13%	4472
7	Pile driving	586	8.05%	5058
8	Concrete pours	81	1.11%	5139
9	Installation or removal of temporary barrier wall	231	3.18%	5370
10	Rolling roadblocks	0	0%	5370
11	Installation of fiber optic cable	5	0.07%	5375
12	Bridge deck work	1582	21.75%	6957
13	Drainage work	165	2.27%	7122
14	ITS work	141	1.94%	7263
15	Bridge demolition	12	0.16%	7275

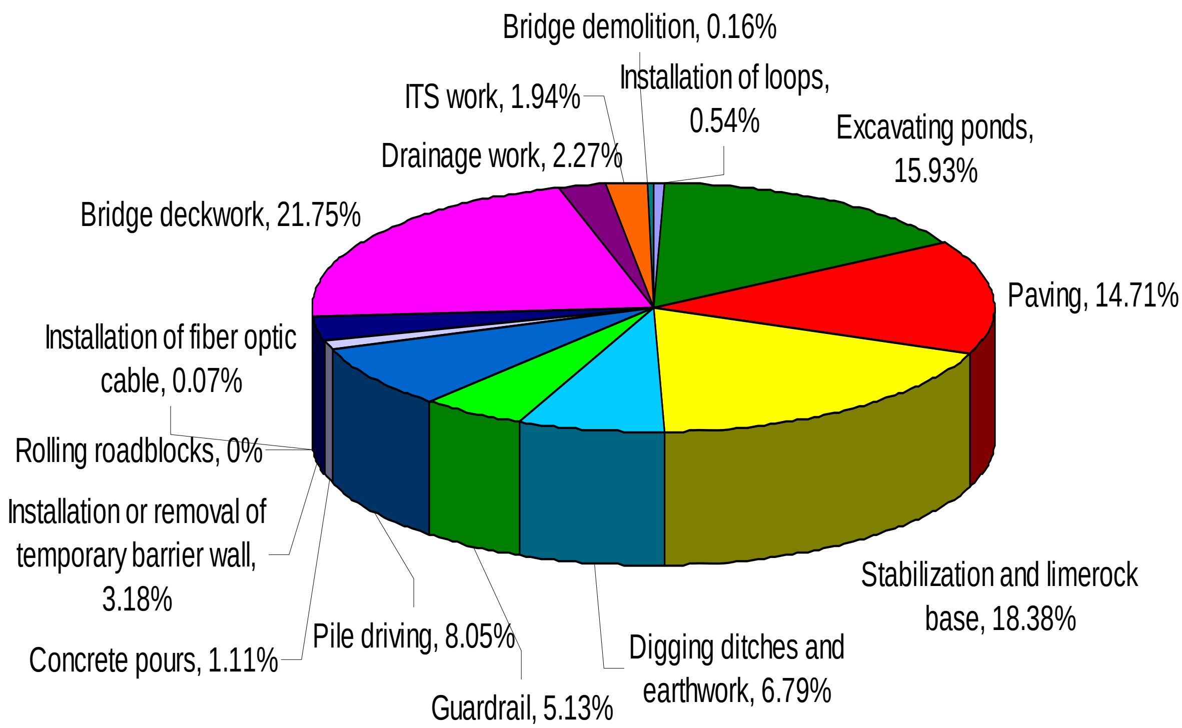

Figure 3-4 Frequency of the different types of work studied

1. Installing traffic loop detectors – This entailed closing one or two lanes of traffic at night where the loops were being placed and cutting in loops into either the asphalt or the concrete. This work is done at night with a work crew and a saw cutting machine. This operation usually took place once the majority of the roadwork was complete. See Figure 3–3.

Figure 3-5 Installing loops

Source: WSDOT (2008), Bellevue, WA

2. Excavating ponds – This involved excavation for a pond with a bulldozer or back hoe and numerous dump trucks on the side of the roadway. It typically does not involve any lane closures, depending on the access for dump trucks coming to and from the work site onto the local roads or onto the interstate. The majority of the pond excavation was completed during the day shift and at the early phases of construction. See Figures 3–4, C–6, C–7, and C–8.

Figure 3-6 Pond excavation

Source: FDOT (2006), Orlando, Florida

3. Paving – This involved placing asphalt onto the road way. The majority of time this involved one lane closure at night time towards the end of the project. This work is performed with an asphalt crew, asphalt paving equipment, broom trucks, multiple dump trucks and rollers. See Figure 3–5.

Figure 3-7 Paving operation

Source: WSDOT (2008), Bellevue, WA

4. Stabilization and limerock base – This involved the placement of limerock and stabilization base for asphalt or concrete roadway widening. These operations were typically performed behind barrier wall (as seen to the right and left in Figure 3–6) and completed during the daytime. There was generally a grader, a roller, water truck, and occasionally dump trucks. See Figures 3–6, C–2, C–3, C–11 and C–12.

Figure 3-8 Placing stabilization

Source: WSDOT (2008), Bellevue, WA

5. Digging ditches and earthwork – This work involved digging ditches on the side of the roadway or placing embankment with a backhoe or bulldozer and a couple of dump trucks. It usually did not require lane closures and was typically completed during the daytime hours off the side of the roadway.

   See Figures 3–7, 3–8, and C–9.

Figure 3-9 Digging a ditch

Source: WSDOT (2008), Bellevue, WA

Figure 3-10 Earthwork

Source: WSDOT (2008), Bellevue, WA

6. Guardrail – This work involved the placement of guardrail. This work typically took place at night with a lane closure involving a piece of equipment to install the posts into the ground and a crew to install the aluminum guardrail by hand. See Figure 3–9.

Figure 3-11 Guardrail

Source: WSDOT (2008), Bellevue, WA

7. Pile driving – This work involved the driving of piles for the bridges. This operation typically did not involve any lane closures on the interstate. This work was performed during the daytime hours. A crane, a pile hammer, and a bridge crew were needed for this work. Pile driving is specialty work where many geotechnical engineers come observe the operations. There are many bystanders while this work was taking place. See Figure 3–10.

Figure 3-12 Pile driving

Source: FDOT (2006), Orlando, Florida

8. Concrete pours – This was for the placement of concrete for either the roadway or for the bridge. This work was mostly completed during the daytime. This work typically involved a lane closure on the city or county streets below the interstate if any lane closures were involved. This work was completed with a concrete work crew and multiple concrete trucks. See Figures 3–11 and 3–12.

Figure 3-13 Daytime concrete pour

Source: WSDOT (2008), Bellevue, WA

Figure 3-14 Nighttime concrete pour

Source: WSDOT (2008), Bellevue, WA

9. Installation or removal of temporary barrier wall – This involved the placement of temporary barrier wall for construction. It always involved one lane closure. This work is done at night with a back hoe and a large truck delivering the barrier wall to the jobsite. Installation and removal of temporary barrier wall was usually done during one of the beginning stages of work and removal of temporary barrier wall was one of the last stages of work. See Figure 3–13 for a photo of barrier wall.

Figure 3-15 Barrier wall

Source: WSDOT (2008), Bellevue, WA

10. Rolling roadblocks – The roadblocks for the placement of the beams for the bridges and for any overhead sign structures. This was done at night, where typically Florida Highway Patrol was used to slow traffic down to about 10–15 mph to create a 15 minute gap in the roadway so that work could be completed. Rolling roadblock operations were not analyzed due to the limited data. This operation requires that the roadway is clear for a period of 15–20 minutes in which the loop

detectors would indicate that the occupancy is zero and the data would not be collected because of the previous findings of occupancy equal to zero indicates bad data as stated in section 4.1.

11. Installing fiber optic cables – This involved the placement of fiber optic cable for the intelligent transportation system and typically did not involve any lane closures. Half the work was done on the side of the roadway during the daytime with an ITS crew and a ditch witch for digging a small area for the placement of the cable and half is done a night time. See Figure 3–14.

Figure 3-16 Installing ITS conduit

12. Bridge deck work – It involved the placement of steel rebar and placement of forms for bridge decks, footers, caps, and columns behind barrier wall (as seen in Figure 3–15). This work was typically done during the daytime and involved bridge crews and delivery of materials such a rebar and concrete. See Figures 3–15, C–1, C–5, C–7, C–8, and C–14.

Figure 3-17 Bridge deck work

Source: WSDOT (2008), Bellevue, WA

13. Drainage work – This work involved the placement of drainage structures and typically did not involve any lane closures. This work was performed during the daytime on the side of the roadway by using boom trucks, backhoes, and rollers. See Figure 3–16.

Figure 3-18 Installing drainage pipes

Source: WSDOT (2008), Bellevue, WA

14. ITS Work – This involved placement of dynamic message boards, installing conduits, fiber optic splices, testing the fiber optic lines, and working in and replacing the hub cabinets along the roadway. Most of this work was performed in the daytime off the side of the roadway. See Figure 3–17.

Figure 3-19 ITS cabinets along side the roadway

Source: WSDOT (2008), Bellevue, WA

15. Bridge demolition – This work was the demolition of the existing bridges. The work was typically done during the daytime hours (depending on the volume of traffic of the cross street below the bridge) with the use of boom trucks, impact hammers, front end loaders and multiple dump trucks. See Figure 3–18.

Figure 3-20 Bridge demolition

Source: WSDOT (2008), Bellevue, WA

Table 3-4 Summary of types of construction work

Type of work	Description of activity	Time of day activity completed typically	Lane closure on interstate?
Installation of loops	Traffic detector loops were being placed into either the asphalt or the concrete. This work was done with a work crew and a saw cutting machine. This operation usually took place once the majority of the roadwork was complete.	Night	Yes
Excavating ponds	This involved excavation for a pond with a bulldozer or back hoe and numerous dump trucks on the side of the roadway. The majority of the pond excavation was completed during the early phases of construction.	Day	No
Paving	This involved placing asphalt onto the road way. This work was performed with an asphalt crew, asphalt paving equipment, broom trucks, multiple dump trucks and rollers.	Night	Yes
Stabilization and limerock base	This involved the placement of base for asphalt or concrete roadway widening. These operations were typically performed behind barrier wall. There was generally a grader, a roller, water truck, and occasionally dump trucks.	Day	No
Digging ditches and earthwork	This work involved digging ditches on the side of the roadway or placing embankment with a backhoe or bulldozer and a couple of dump trucks off the side of the roadway.	Day	No
Guardrail	This work involved a piece of equipment to install the posts into the ground and a crew to install the aluminum guardrail by hand.	Night	Yes
Pile driving	This work involved the driving of piles for the bridges. A crane, a pile hammer, and a bridge crew were needed for this work. This is specialty work where many geotechnical engineers come observe the operations..	Day	No

Type of Work	Description of activity	Time of day work completed typically	Lane closure on interstate?
Concrete pours	This was for the placement of concrete for either the roadway or for the bridge. This work was completed with a concrete work crew and multiple concrete trucks.	Day	No
Installation or removal of temporary barrier wall	Involved the placement or removal of temporary barrier wall for construction. This work is performed with a back hoe and a large truck delivering the barrier wall to the jobsite. Installation and removal of temporary barrier wall was usually done during one of the beginning stages of work and removal of temporary barrier wall was one of the last stages of work.	Night	Yes
Rolling roadblocks	The roadblocks for the placement of the beams for the bridges and for any overhead sign structures. This was done at night, where typically Florida Highway Patrol was used to slow traffic down to about 10–15 mph to create a 15 minute gap in the roadway so that work could be completed.	Night	No
Installation of fiber optic cable	This involved the placement of fiber optic cable for the intelligent transportation system. This work was done with an ITS crew and a ditch witch for digging a small area for the placement of the cable.	Day	No
Bridge deck work	Bridge deck work – It involved the placement of steel and placement of forms for bridge decks, footers, caps, and columns behind barrier wall. This work was typically involved bridge crews and delivery of materials such a rebar and concrete.	Day	No
Drainage work	Involved the placement of drainage structures and pipe. This work was performed using boom trucks, backhoes, and rollers off the side of the roadway.	Day	No
ITS work	This involved placement of dynamic message boards, installing conduits, fiber optic splices, testing the fiber optic lines, and working in and replacing the hub cabinets along the roadway	Day and Night	No
Bridge demolition	This work was the demolition of the existing bridges. The work was typically done with the use of boom trucks, impact hammers, front end loaders and multiple dump trucks.	Day	No

3.2.2 Case Numbering

Each activity performed at a specific 90 minute period had an individual case number assigned to it for each day the work was taking place and data were collected for each of these cases. Daytime work was typically completed in 8 hour shifts and night time work was completed in 10 hour shifts. For the data collected during these shifts, they were broken down into 90 minute segment, called stratum or strata, as discussed in Section 3.2.3. Each of these strata had 3 cases. See Table 3-5 for an example; Case 1 was during a construction period, Case 10,001 was during a pre construction period, and Case 100,001 was during a post construction period. More specifically, cases 1-5,572 represent the during construction data. Cases 10,001-15,572 represent the year prior to construction and cases 100,001-105,572 represent the year after construction for the controls for this analysis. As an example, consider Cases 1-4 which represent 4 strata that had 3 cases in each stratum from the activities of one work shift, 10:00 pm to 6:00 am. See Table 3-6 for an example numbering of the strata and the 3 cases for each stratum. Each stratum was for a specific type of work (i.e., no two types of work were combined for data collection).

Table 3-5 Sample of data collected – strata and cases

Case Number	Date	Date	Time Of Work	Loop Dectector	Direction	Time-Range	Loop Detector Range	Station As Shown In Dailies	Type Of Work	Type
1	6/2/2002	Sunday	23:30	17	E	22:30–24:00	17-17	758-792	paving	3
2	6/3/2002	Monday	1:30	17	E	0:30–2:00	17-17	758-792	paving	3
3	6/3/2002	Monday	4:00	17	E	2:30–4:00	17-17	758-792	paving	3
4	6/3/2002	Monday	6:00	17	E	4:30–6:00	17-17	758-792	paving	3
10001	6/3/2001	Sunday	23:30	17	E	22:30–24:00	17-17	758-792	paving	3
10002	6/4/2001	Monday	1:30	17	E	0:30–2:00	17-17	758-792	paving	3
10003	6/4/2001	Monday	4:00	17	E	2:30–4:00	17-17	758-792	paving	3
10004	6/4/2001	Monday	6:00	17	E	4:30–6:00	17-17	758-792	paving	3
100001	6/1/2003	Sunday	23:30	17	E	22:30–24:00	17-17	758-792	paving	3
100002	6/2/2003	Monday	1:30	17	E	0:30–2:00	17-17	758-792	paving	3
100003	6/2/2003	Monday	4:00	17	E	2:30–4:00	17-17	758-792	paving	3
100004	6/2/2003	Monday	6:00	17	E	4:30–6:00	17-17	758-792	paving	3
101	8/26/2002	Monday	9:00	18	E	7:30–9:00	18-18	797	fiber optic cable	11
102	8/26/2002	Monday	12:00	18	E	10:30–12:00	18-18	797	fiber optic cable	11
103	8/26/2002	Monday	15:00	18	E	13:30–15:00	18-18	797	fiber optic cable	11
10101	8/27/2001	Monday	9:00	18	E	7:30–9:00	18-18	797	fiber optic cable	11
10102	8/27/2001	Monday	12:00	18	E	10:30–12:00	18-18	797	fiber optic cable	11
10103	8/27/2001	Monday	15:00	18	E	13:30–15:00	18-18	797	fiber optic cable	11
100101	8/25/2003	Monday	9:00	18	E	7:30–9:00	18-18	797	fiber optic cable	11
100102	8/25/2003	Monday	12:00	18	E	10:30–12:00	18-18	797	fiber optic cable	11
100103	8/25/2003	Monday	15:00	18	E	13:30–15:00	18-18	797	fiber optic cable	11

Table 3-6 Strata and case numbers

	Case numbers		
Strata	During construction	Before construction	After construction
1	1	10,001	100,001
2	2	10,002	100,002
3	3	10,003	100,003
4	4	10,004	100,004
5	5	10,005	100,005
6	6	10,006	100,006
7	7	10,007	100,007

3.2.3 Timing of Construction Work

The contractor worked different hours on the various activities. The daytime versus night time operations were driven by the allowable lane closures. Due to the volume of traffic on Interstate 4 and the various cross streets beneath, most lane closures were only allowed at night. The break down of the timings of this study was based on broadly expected traffic patterns.

The daytime work shifts were primarily from 7:00 am until 3:00 pm. The data were collected for three 90 minute segments during that time; from 7:30 am to 9:00 am (peak morning traffic), 10:30 am to 12:00 pm (off peak morning traffic), and from 1:30 pm to 3:00 pm (afternoon off peak traffic).

The lane closures were allowed on I–4 from 10:00 pm until 6:00 am. The data for night time work were collected for four 90 minute segments during that time; from 10:30 pm to 12:00 am, 12:30 am to 2:00 am, 2:30 am to 4:00 am, and 4:30 am to 6:00 am.

See Figure 3-19 for a graph showing the traffic volume at 4 locations. This figure shows the break down of the hourly volumes to show why the data were collected during the times indicated above. Station 21 is located to the north of SR 482 (Sand Lake Road). Station 31 is the loop detector station located to the north of SR 423 (John Young Parkway). Station 51 is south of SR 414 (Maitland Boulevard). Station 62 is north of SR 434. The graphs show the peak and off peak hours. This data is from 2002 on a Monday. The “Night 1”, “Night 2”, etc represent the time segments discussed above.

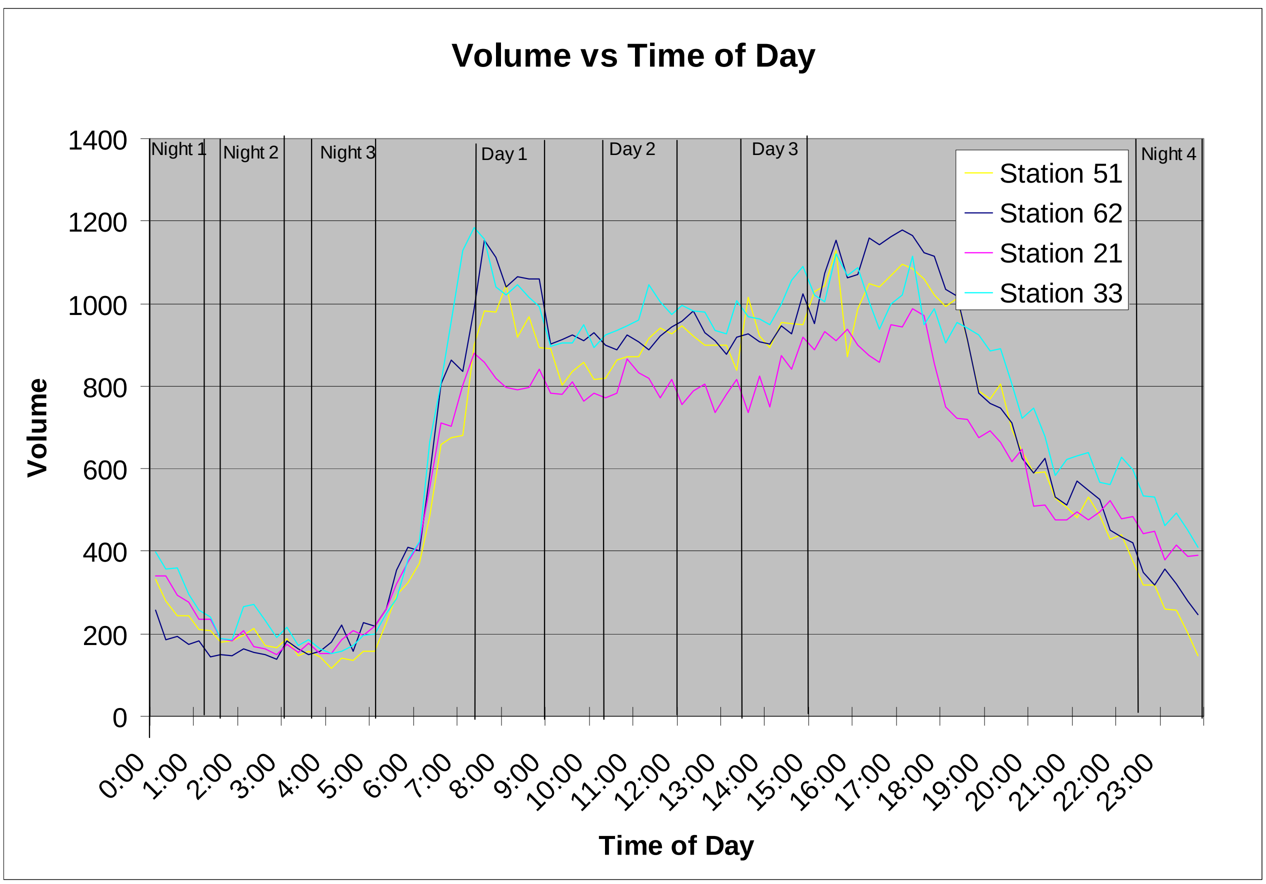

Figure 3-21 Volume versus time of day

3.2.4 Roadway Characteristics Inventory

Understanding the relation between the roadway characteristics and the various impacts to the traffic operations is important to consider when conducting studies such as this. For example, ramps nearby construction zones can also impact the flow of traffic. The FDOT roadway characteristics inventory (RCI) was obtained from FDOT and was used to correlate the loop detector number with the geometric characteristics. Information in the RCI includes the following information:

- Loop detector direction location (eastbound or westbound)
- Straight or curved roadway segment (as indicated in the "Radius" column – value of 17189 indicates a curved section, a value of 0 indicates a straight section of roadway. The value of 171189 was a value in the information obtained from FDOT.)
- Number of traffic lanes in the area
- Median type (grass, barrier wall, guardrail etc.)
- Width of median in feet
- Type of pavement (asphalt or concrete)
- The number of ramps located by the loop detector (0, 1, 2, or occasionally 3) within 1/2 mile of the loop detector

The location of the nearby upstream on ramps and off ramps as well as the nearby downstream on ramps and off ramps were also calculated and incorporated into this study. The location of each loop detector was also incorporated into the analysis that took place. See Table A–2 in Appendix A for the RCI inventory.

3.2.5 Loop Detector Data

The loop detectors along I–4 are placed approximately every one half mile and are dual loop detectors. See Table B–1 and Figures B–1 to B–8 for loop detector locations. The FDOT system records the 30-second readings on the volume, speed and occupancy. This data was aggregated for analysis. Since the 30–second data have random noise and is difficult to work with in a modeling framework, the 30–second data was combined into 15–minute level in order to calculate averages and standard deviations.

3.3 Data Exploration

The purpose of this research is to develop models for exploring how construction can impact traffic flow, to determine which types of construction have the highest impact to the traffic operations on a freeway. This study examines how construction activity reflects congestion activity and how the roadway geometrics impact congestion during construction.

The data points could be best analyzed by collecting the loop detector information. The data points (locations of construction activity) were cross referenced to the loop detectors on the roadway. A total of 16,716 data points were collected, however due to the elimination listed below, there were 7,275 data points that could effectively be analyzed because of missing data or elimination due to the criteria discussed in the following paragraph. Each data point is a construction activity taking place at a certain time and location as seen in Table 3–2. The same 7,275 points were used to collect the loop detector data for the year prior to construction and for the year after construction. The purpose of collecting the data for the same day of the week the previous year and proceeding year is to have a comparison, to take into account for all the factors impacting the slowdown of traffic occurrence such as driver population, season, day of week, and location on the freeway, etc.

The first step was to run a Java script to extrapolate the 30 second readings from the data warehouse from the loop detector data. This data was then run through SAS (SAS Library Repeated Measures ANOVA Using SAS PROC LRM, 1997.) to aggregate it into 15 minute averages for the hours and days of construction for the speed, occupancy, and volume. There was one data point for all three lanes. It is very common for loops to fail during construction due to being cut or milled through, or because of periodic hardware or software problems and either no data is collected or unrealistic values are recorded. The values with the following characteristics in the 30 second readings were eliminated to remove the outliers:

Occupancy > 100

Speed = 0 or Speed >100

Flow = 0 or Flow >25. (Chandra and Al–Deek, 2004).

Some data points could not be analyzed due to the constraints listed above. However, due to the large number of data points collected, it was not an issue.

The types of work that could be analyzed were:

Excavating pond

Paving

Stabilization and limerock base

Digging ditches and earthwork

Guardrail

Pile driving

Installation or removal of temporary barrier wall

Drainage work

ITS work

Bridge deck work

The following areas did not have sufficient data for analysis (< 100 observations) as detailed in Table 3–3 and Figure 3–2:

Installing loops

Concrete pours

Rolling roadblocks

Installing fiber optic cable

Bridge demolition

Each of the 7,275 represents a 1 ½ hour segment which was further broken down into six – fifteen minute segments for analysis. The 15 minute time segment with the highest volume and occupancy and the time segment with the lowest speed for each 1 ½ hour time segment was evaluated to identify the worst case scenario for analysis. Similarly, for the cases prior to construction and post construction, the data for the worst 15 minute segment for the 90 minute segment were collected to eliminate the effects of random variation. The data collected for the year before the construction and the year after construction were used for the control.

3.4 Summary

This chapter discusses background of the three construction projects. Table 3–1 gives a brief summary on the projects. The next items discussed are the data collection; the types of work evaluated, the timings of the work, the roadway characteristics inventory, the loop detector data, and the data exploration. The collection of data was time consuming because of the volume of reports that were used to collect the data. The methodologies discussed in the next two chapters were the controlling factors in deciding which pieces of information to collect.

CHAPTER 4 MATCHED CASE LOGISTIC REGRESSION

4.1 Model Definition

For a binary variable the logistic regression analysis may be used to estimate the probability of a future event of y (0 or 1) based on a set of independent parameters. Matched case studies can be used to control variables and logistic regression is helpful for estimating relationships. The goal of this chapter was to conduct an explorative analysis to determine if there was an association between the traffic data and the construction variables provided the geometry variables were kept unchanged. This was done by matching data that has the same characteristics (geometric, time of the day, etc) for data both with and without the presence of construction to ensure that there was no other difference. Logistic regression is used to prove if there was a difference in the matched data with and without the presence of construction. However, the problem may still be set up as a binary classification problem for various construction activities. It would entail estimating the logit model for the construction activity based on the known values of traffic parameters.

$$\log(p(y=1)/1-p(y=1)) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \quad (1)$$

If the traffic parameter(s) were significantly related to the binary target variable then it would indicate that the construction activity of that particular type was significantly impacting the traffic flow. The traffic data with and without the construction activity was used for analysis. There was a problem, however, that the measure of traffic flow on the freeway, as observed by the traffic surveillance system consisting of loop detectors, might be impacted by geometric design, freeway location characteristics, time of and/or day of week. The external factors must be accounted for in order to accurately assess the impact of construction activities.

There was an assumption of a normal distribution. With this assumption, this study can make standardized comparisons across different data points. A sensitivity analysis was not needed because the data points were not collected when two different types of work were simultaneously taking place.

4.2 Methodology

This chapter developed simple models (involving one covariate at a time) to examine information on traffic flow characteristics for both construction and non–construction cases at the same time controlling other external factors. It inherently took into consideration geometry and location characteristics as well as other characteristics. This could be achieved using a within–stratum (as described below) analysis of a binary outcome variable Y (construction activity versus no construction activity) as a function of traffic flow variable X_k from matched cases where a matched set (henceforth referred to as stratum) could be formed using construction site, time, season, day of the week, etc., so that the variability due to these factors is controlled. In epidemiological studies, this is known as a matched case–control study. Each case refers here to a data recorded on a day at a specific time, location and construction activity while control refers to traffic flow observations from the same location during the same week of the year, previous or next year (i.e., before or after construction). Each piece of data during construction and its corresponding non–construction cases make up a matched stratum. The steps involved in the sampling procedure may be described as follows:

(i) Select a construction site (based on the data collection procedure described in Chapter 3), and identify loop detector(s) nearest to this location. Measure traffic flow characteristics from that loop detector at a time period during the construction. Use the same loop detectors and time period, measure traffic flow characteristics over the non–construction day, the same day of the week from exactly one year before the construction took place and after the construction is complete. The observations, corresponding to the type of work during construction and before and after construction, together form one stratum.

(ii) Repeat step (i) for each of the various selected locations with similar construction activities to form the strata for each data point.

(iii) In order to identify the traffic flow variable, the within–stratum analysis is used to identify traffic flow variables that are associated with the binary outcome (construction/no–construction) variable Y while controlling variability due to all other external factors that formed the strata.

Since there is pre construction and post construction data, matched case methodology can be used. The matched case sampling strategy controls for the variables such as the roadway geometries, location of work, and type of construction. The post construction, during construction and pre construction data for each activity, time and day are assigned the same number for the matched case procedure. The geometric characteristics, time of day, day of week, type of construction work, location, etc. was controlled (Aty, et al., 2004).

The logit transformation:

$$g(x) = \ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = \beta_0 + \beta_1 x \quad (2)$$

shows how the function of dependent variables produces independent variables as a linear function. The conditional mean of *Y* (dummy variable is where there is construction or no construction) $\pi\ (x) = E\ (Y|x)$ *is* given *x* using logistic distribution. The likelihood of construction impact will be on the left of the equation. Given that this is linear, the equation is $g(x) = \beta_0 + \beta_1 x$. The likelihood of construction impact for an increase in 1 unit of X (when x is continuous) is β_1 . For binary x, β_1 is the change in likelihood of construction when x=1, indicating the presence of the variable denoted by x. For example, for any value of X, $\beta_1 = g\ (x+1) - g\ (x)$. (Agresti, 2002)

It needs to be understood that the logistic regression does not indicate causality. In effect, the purpose of this analysis is not to conclude that for example, the increase / decrease of speeds increase the likelihood of construction. Should there be any significant relationship, it should only be interpreted as the increase / decrease of speeds (or any traffic variable) is associated with an increased chance of construction presence.

As previously mentioned, in order to evaluate the conditions during the worst case scenario, for each 90 minute time segment, the speeds were evaluated during the slowest 15 minute segment. Similarly, the 15 minute segment with the maximum occupancy and maximum volumes were evaluated in this study.

Simple models were developed. This involved one covariate in order to evaluate the individual parameters; speed, occupancy and volume. The likelihood ratio test also known as the chi–square difference was evaluated to determine which parameters were significant.

4.3 Logistic Regression Analysis

The data were analyzed by utilizing SAS using the PHREG procedure. The PHREG procedure is a semi-parametric procedure/ regression analysis that fits odds models. Analysis with matched case logistic regression initially involves looking at the p–value corresponding to chi squared test statistic. If the P-value is less than .05, it indicates that this factor is significantly affected by presence of construction; these factors were analyzed. Simple models were evaluated (i.e. a model with one variable).

The odds ratio demonstrates the likelihood of an impact for an increase of 1 unit of x. (Agresti, 2002). If the odds ratio varies significantly from one, then there is an indication that there is a statistically significant impact from construction. The significance of the impact increases as the odds ratio increases from a value of one. To ensure that we are able to detect the construction impact the comparison between before and after construction is also carried out since they also make a matched stratum (matched location/time of day/day of week.).

4.3.1 Simple Models for Comparing “Before” Versus “During” Construction

When analyzing the data for all types of construction “before” versus “during”, as seen in Table 4–1, there was a significant difference between “before” versus “during” construction speed, occupancy, and volume. This tells us that traffic is impacted by construction. The control was the “before” data and the “during” data was compared to the “before” data. The speed and the volume decrease while the occupancy increases. This is what can be anticipated once a construction project begins on a roadway. The greatest traffic operations impact was on the volume of traffic flowing on the interstate. Often drivers avoid construction areas or modify the timings of their commutes, thus accounting for the reduction in volume. A reduction in volume can also be attributed to lower speeds.

Table 4-7 Results of three simple models for speed, occupancy, and volume, “before” versus “during” construction data

Covariate	Parameter Estimate	Odds Ratio	Pr<Chi Squ	Significant
Min Speed	–0.05715	0.944	< .0001	Yes
Max Occupancy	0.09634	1.101	< .0001	Yes
Max Volume	–0.21415	0.807	< .0001	Yes

4.3.2 Simple Models for Comparing “During” Versus “After” Construction

When comparing the “during” construction data to the “after” construction data, the speed and occupancy had a significant difference, as seen in Table 4–2. The control was the “after” data and the “during” data was compared to the “after” data. The speed decreased while the occupancy on the traffic loops increased in the presence of construction activities. Occupancy had the greatest impact. It is interesting to note that traffic volume is not significantly different with or without construction activities.

Table 4-8 Results of three simple models for speed, occupancy, and volume, "during" versus "after" construction data

Covariate	Parameter Estimate	Odds Ratio	Pr<Chi Squ	Significant
Min Speed	–0.04941	0.952	< .0001	Yes
Max Occupancy	0.06748	1.07	< .0001	Yes
Max Volume	0.01129	1.011	0.33	No

4.3.3 Simple Models for Comparing "Before" Versus "After" Construction

When analyzing all the data for all types of construction for "before" versus "after" construction, there was a significant difference between "before" and "after" construction with speed, occupancy and volume, as seen in Table 4–3. The control was the "after" data and the "after" data was compared to the "before" data. The speed and volume increased after construction and the occupancy was reduced after construction. The greatest impact was on occupancy. There is a difference in traffic parameters in before and after data because once construction is complete and capacity has been added to the freeway, people tend to change their driving habits. Perhaps individuals that took surface streets prior to construction have modified their driving patterns to incorporate the interstate as part of their driving patterns.

Table 4-9 Results of three simple models for speed, occupancy, and volume, "before" versus "after" construction data

Covariate	Parameter Estimate	Odds Ratio	Pr<Chi Squ	Significant
Min Speed	–0.0264	0.974	<.0001	Yes
Max Occupancy	0.01175	1.012	<.0001	Yes
Max Volume	–0.44338	0.642	<.0001	Yes

4.4 Summary

The main objective of this chapter was to conduct an explorative analysis to determine if there was an association between the construction data and no construction data. This was done by matching the variables to ensure that there is no other difference. Logistic regression proved there was a difference between data with and without the presence of construction.

Logistic regression was the analysis method chosen for this chapter for several reasons. Since there was data that can be matched and dependent variables can be controlled, it was very useful. This regression also produces a odds ratio that shows the likelihood of an impact.

Upon evaluating the simple models for comparing “before” versus “during”, it was determined that the speed, occupancy, and volume had a significant impact. When evaluating the simple models for comparing “during” construction data to the “after” construction data, the speed and occupancy had a significant difference; however the volume did not have a significant difference. When analyzing simple models for “before” versus “after” construction, there was a significant difference with speed, occupancy, and volume.

CHAPTER 5 LINEAR REGRESSION AND ANALYSIS OF COVARIANCE

5.1 General

The information in this chapter quantifies the impact of the construction activities and the geometric conditions of Interstate 4 on speed, volume, and occupancy utilizing linear models with categorical and continuous independent variables. The data cross-referenced the roadway geometric conditions from which models were developed. The linear models are a sub-class of General(ized) Linear Models (GLM) of which Linear Regression and Analysis of Covariance (ANCOVA) are special cases. Linear Regression and ANCOVA were used to understand the presence of geometrics before, during, and after construction activities. Models for speed, occupancy, and volume were generated for before, during, and after construction. The models were then compared for similarities and differences for impacts from construction activities and determined how the presence of construction and roadway improvements changed the impacts from the geometric roadway conditions.

Analysis of covariance (ANCOVA) is a specific type of GLM. While linear regression model (LRM) is a linear model for modeling a continuous response with only continuous predictors, ANCOVA is used when there are both categorical and continuous predictor variables. It is used when there is at least one categorical variable or at least one continuous predictor variable and when there is one continuous dependent variable. It also compares the relationship between a dependent variable and an independent variable with different levels of a categorical variable. ANCOVA is a combination of ANOVA and regression for variables that are continuous. It tests if certain factors have an effect after removing the variance from quantitative predictors or covariates. Since the variability is included, ANCOVA increases the statistical power because it includes covariates.

The assumptions are that the residuals are independent, have a normal distribution, and there is homoscedasticity with the residual variance, i.e. the values of x are independent from the categorical variable values. It also assumes there is no error in the independent variables and that the relationship between the covariate and Y is linear (Argesti, 2002).

The previous chapter was concerned with the association of the construction activity and its effect on traffic variables – speed, volume, and occupancy. In this chapter, an attempt was made to quantify the impact of different construction activities on speed, occupancy, and volume. A linear model of the form

$$Y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \ldots + \varepsilon \quad (3)$$

is fit to the data where Y represents the dependent traffic variable (speed , occupancy, or volume) and $x_1, x_2, \ldots x_n$ represents the geometric and construction activity related variables.

The logistic regression model showed that construction has an impact on speed, occupancy, and volume, irrespective of the type of construction. The response is the likelihood of construction. It was a "bird's eye" view of the impact of construction.

The linear regression and Ancova purpose was to quantify the impact of the different construction activities and the geometric conditions of the roadway on speed, volume, and occupancy. The response is the variable speed, occupancy and volume. This told us that depending on the time of the construction, the impact was different for different types of activities and also for the different geometric parameters. During the peak hours there was an impact from construction and the impact from roadway geometrics was impacted the most, during off peak hours, there was not as much of an impact.

5.2 Linear Regression Definition

A linear regression model uses data that arise from multivariate measurements. At least one of these variables must be a response and the other measurements can be measurements of levels (categories) or continuous measurements. The variables other than the response are designated as predictors or covariates. The linear regression model then estimates parameters of a linear combination of the predictors (similar to Equation 3 above). These parameters are assumed to follow a normal distribution. It estimated parameters that also contained some errors and followed a normal distribution. The outcome is a linear function of functions of the covariates that can predict the mean value of the response. LRM utilizes the equation $Y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \ldots + \varepsilon$. The LRM shows a relationship between variables as a mean. When one of the covariates is categorical, each level of the categorical variable is coded as a binary variable. The effect of such a coding is that a parameter is added that gets included with the constant term for each level of the categorical variable.

In these models, certain assumptions are made about the error ε. These assumptions make it possible to compile confidence intervals and can be used for hypothesis testing. These assumptions are:

- The errors are independent of each other and are normal

- The mean of these errors $E(\varepsilon) = 0$
- The errors are homoscedastic (the variance of the errors does not depend on x)

A significant portion of the model interpretation is the hypothesis testing. The model is fit, and the parameters are estimated, but the question that needs to be answered is what confidence we have in the parameters that the model has come up with, how stable they are (will they change significantly if we draw a different random sample), and if the model does enough to explain the variability in the response. As mentioned earlier, the parameters are assumed to be normal, and therefore can be associated with standard errors and confidence intervals. This makes it easier to test whether each of the parameters is significant (or significantly different from 0). The test is usually stated in the form of a Null hypothesis: H_o. An alternative hypothesis (H_a) is constructed that makes a contrasting statement to $H_{o.}$ A z-test is performed (as the parameters are normal), and the resulting z-statistic or p-value can be used to test for the parameter being different from zero. For instance, a simple model for Y against x can be stated as

$Y = \alpha + \beta x$

For this model to be significant, we require at least β to be different from zero. The null hypothesis is stated as

H_o: $\beta = 0$

H_a: $\beta \neq 0$

Since β is normal and the standard error of this coefficient is available, a simple z-test on β will determine if it is significantly different from 0. If it is, then we can confidently state (within the limits imposed by the confidence levels) that the model is significant. The same concept is extended when there is more than one x involved and p-values can be used to test the significance of each parameter.

In this thesis, there were three separate groups of variables or categories of unrelated variables that were part of the analysis: construction activities (listed in section 5.3), curved or straight roadway segments, and type of median (grass, grass with guardrail, or concrete barrier wall). Each of these categories of variables represents different levels of the same variable. For example, a segment can be either straight section or a curved section, and can be represented by a binary variable. Similarly, the category median type with three levels (grass, grass with guardrail, or concrete barrier wall) can be represented by two binary variables. For a category that represents a variable with *n* levels, there are *n-1* binary variables required. The other remaining level is usually chosen as the base case. SAS chooses a base case and all the subsequent variable in the group of variables are compared to the base case. LRM selects one parameter, the one with least impact to be a base case. In the models to be considered henceforth, there are three sets of variable groups:

- Construction activity related variables: These have 6 levels; therefore there are 5 binary variables and one base case. The variables are discussed in detail in section 5.3. The data set for each time segment were evaluated separately since some of the work did not take place during all of the time segment described in section 5.3. If the number of construction data for the construction variables were greater than 3% of the total number of construction variable points, then the variable was entered into the analysis. This meant that there were fewer than 5 the binary construction variables for some of the time segments. The guardrail installation and barrier wall removal and installation was the base case for the night time and peak morning time segments and the pile driving, bridge demolition, and bridge deck work was the base case for the off peak hour time segments.

- Curvature of roadway segments: These have 2 levels – straight and curved roadway segments. Therefore, one binary variable is required and the curved segment is chosen as the base case.
- Median type: There are three levels, so two binary variables are required, and the median barrier wall is chosen as the base case.

There were 5 variables that were not part of a category (or in other words, these are the interval variables) which were: number of ramps, upstream on ramps, upstream off ramps, downstream on ramps, and downstream off ramps. These 5 variables are continuous and are not mutually exclusive.

A correlation test was run to check for multicollinearity among the continuous variables. The results showed that these variables are not highly correlated. None of the correlation coefficients were close to 1.0, indicating that multicollinearity was not an issue.

The dependent variables were the speed, occupancy, and volume. The independent variables were those mentioned in the previous paragraphs.

The majority of variables discussed in this chapter fall within the 95% confidence interval; however, variables within the 90% confidence interval were also analyzed. In Tables 5-1 through

Tables 5-52 any shaded areas were outside of the 90% confidence interval and not included in the discussion.

The estimates for the volume intercepts were all normalized back to the 30 readings for Tables 5-1 through 5-52. The volume is accounted for over three lanes of traffic for 15 minute segments over a 90 minute time period (or less if some observations are missing). This was the reason for the low values of the volume intercept estimates seen in the tables in this chapter.

5.3 Pre Analysis Exploration

The next step was to evaluate the general impact of the different types of work at various times of the day or night. Similar work was grouped together. For example, work that had similar types of equipment that took place at similar times of the day or that was in the same general category (bridge work) were grouped together for analysis.

The groups formed were:

1. ITS work and installing loops
2. Stabilization and limerock base and drainage work
3. Pond excavation, digging ditches, and earthwork
4. Pile driving, bridge demolition, and bridge deck work
5. Paving
6. Guardrail and barrier wall

For the purpose of analyzing the data, the data collected were broken down into four time categories representing the time of day of the expected traffic patterns:

10:30 pm to 5:00 am – Representing the night traffic.

7:00 am to 8:30 am – Representing the morning peak traffic.

8:30 am to 1:30 pm – Representing the morning/ early afternoon off peak traffic.

1:30 pm to 3:00 pm – Representing the afternoon off peak traffic.

There was no ongoing construction during the afternoon peak hours; therefore the afternoon peak hour category is not discussed.

5.3.1 ITS work and Installing Loops

ITS work and installing loops were grouped together because the activities were for the same construction element. The majority of the work took place at night, however; some of the work took place during the daytime. Figure 5–1 shows the observations versus time of day for the ITS work. There was insufficient data points during the night time work and the peak morning hours therefore they were not input into the analysis during those time segments.

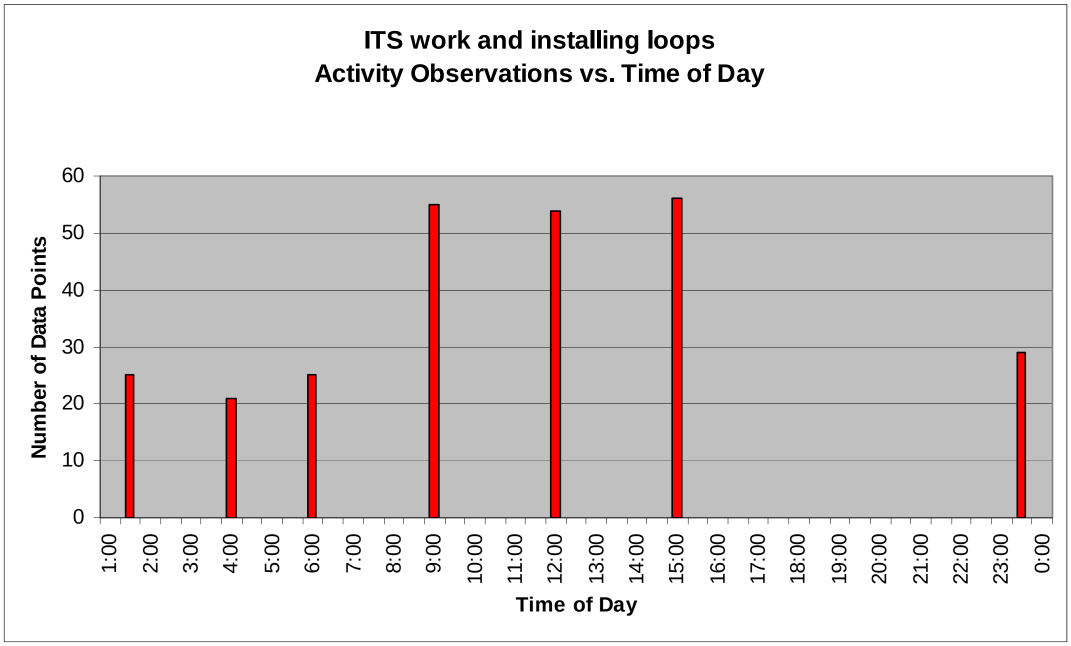

Figure 5-22 Installation of loops and ITS equipment observations versus time of day

5.3.2 Stabilization and Limerock and Drainage Work

The two operations, stabilization and limerock and drainage work operations were grouped together because the operations involve similar equipment and the timings of the operations were about the same. As can be seen in Figure 5–2, the majority of these activities took place during the daytime. Occasionally, activities happened at night because of issues with access for equipment or materials.

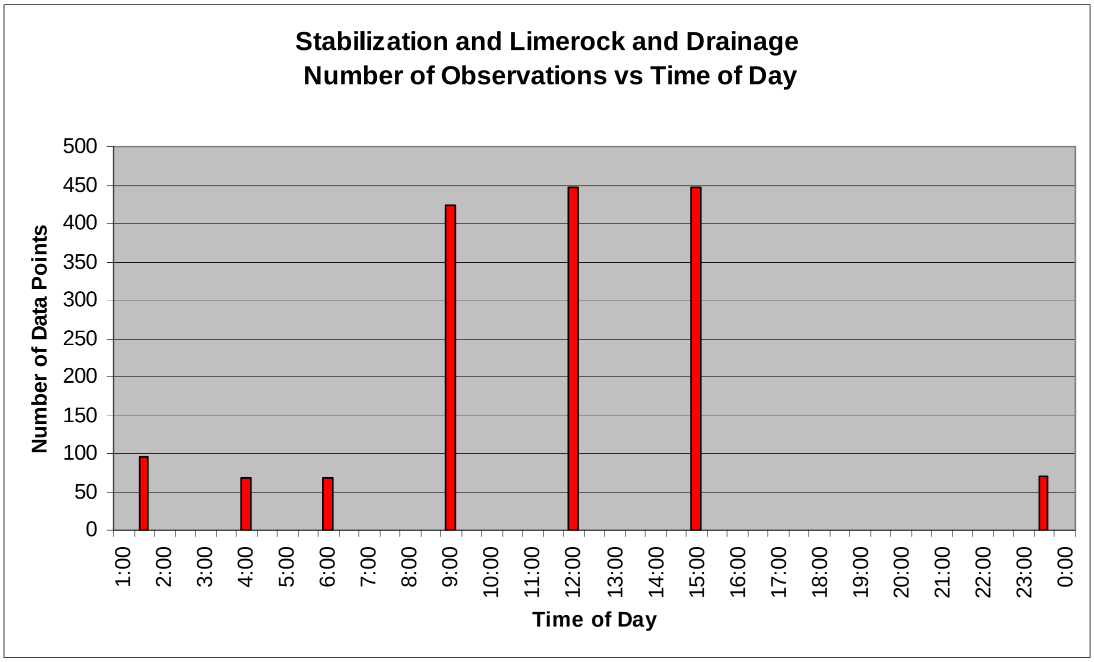

Figure 5-23 Stabilization and limerock and drainage observations versus time of day

5.3.3 Pond Excavation, Digging Ditches, and Earthwork

Pond excavation, digging ditches, and earthwork operations were grouped together because the operations involved similar equipment and the timings of the operations were about the same. As can be seen in Figure 5–3, the majority of these activities took place during the daytime. Occasionally activities happened at night because of issues with access to and from the interstate for equipment or materials.

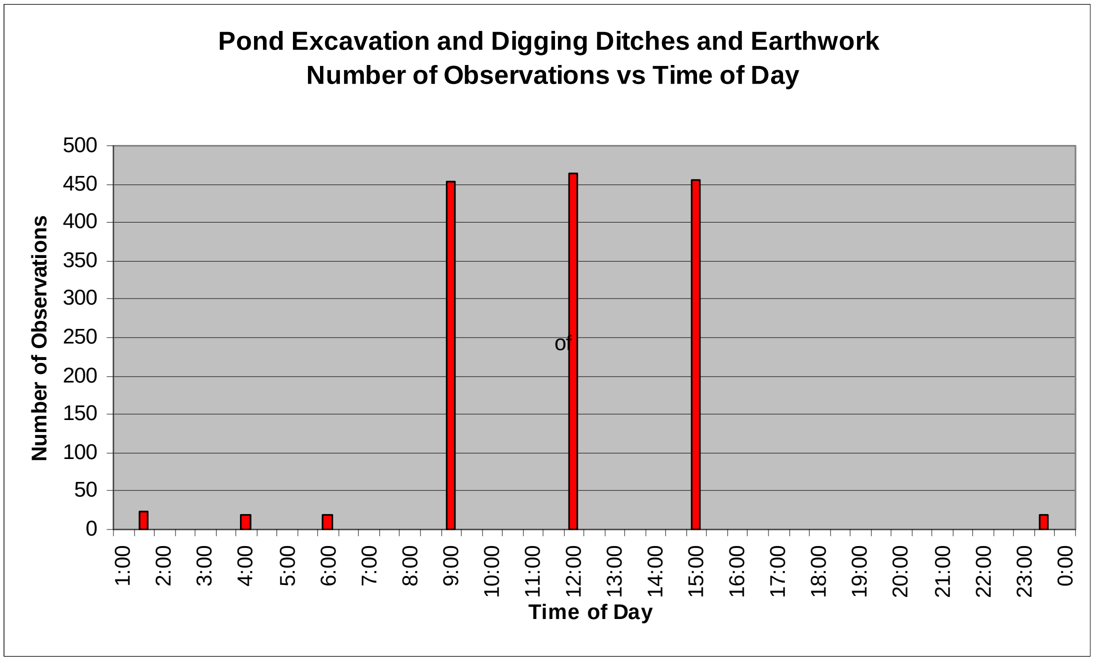

Figure 5-24 Pond excavation, digging ditches, and earthwork observations versus time of day

5.3.4 Bridge Work

The bridge work includes pile driving, bridge demolition and bridge deck work. They were grouped together because the activities taking place were for the construction of bridges and the timings of the operations were about the same. As can be seen in Figure 5–4, the majority of these activities took place during the daytime. Occasionally activities happened at night because of issues with access for equipment or materials. Bridge work was the base case for the off peak hours.

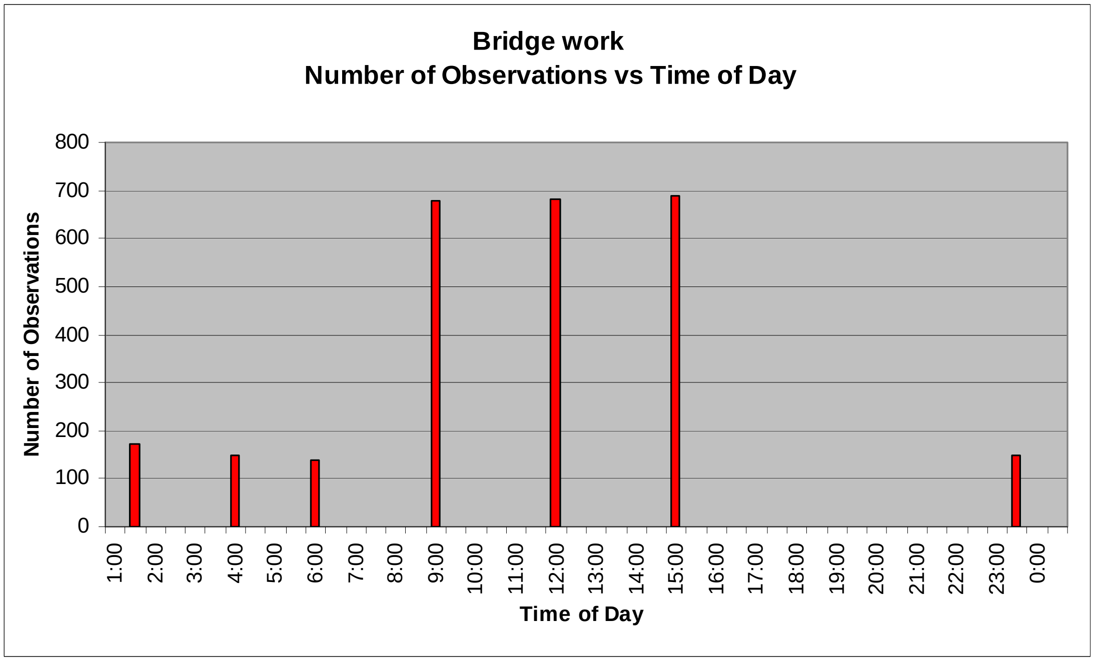

Figure 5-25 Bridge work observations versus time of day

5.3.5 Paving

Paving was in a group by itself. As can be seen in Figure 5–5, the majority of paving activities took place at night because of the need for lane closures. There were insufficient data points during the off peak hours, therefore during those time categories the paving variable was not entered into the analysis.

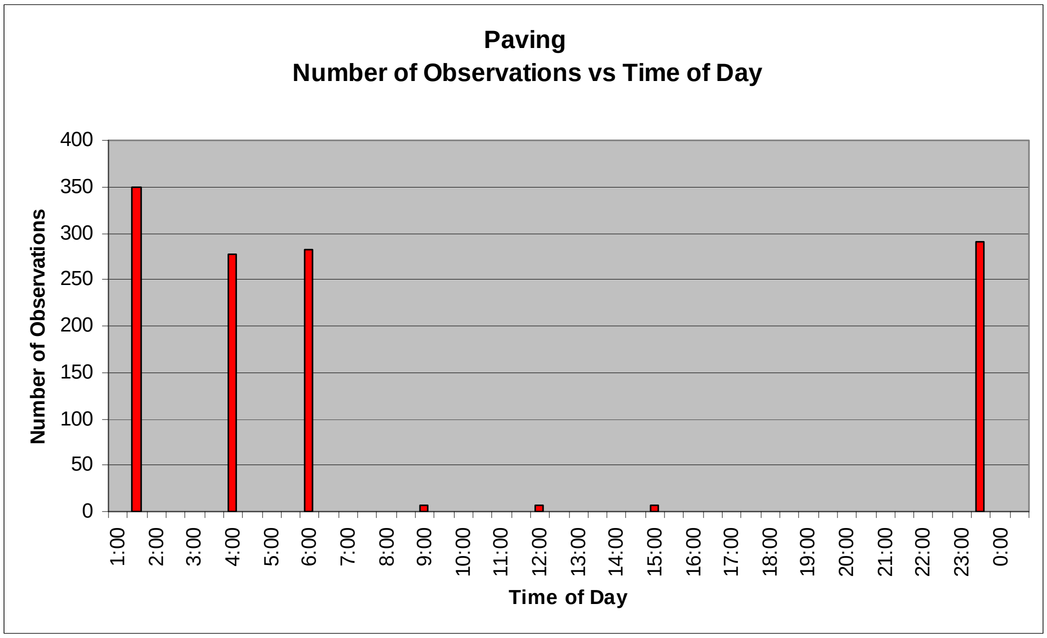

Figure 5-26 Paving observations versus time of day

5.3.6 Remove and Install Barrier Wall and Install Guardrail

These two operations were grouped together because timings of the operations were about the same and because both activities involved installing materials on the side of the roadway. As can be seen in Figure 5–6, the majority of these activities took place at night. This is the base case for night time work. There were insufficient data points during the off peak hours, therefore during those time categories this variable was not entered into the analysis.

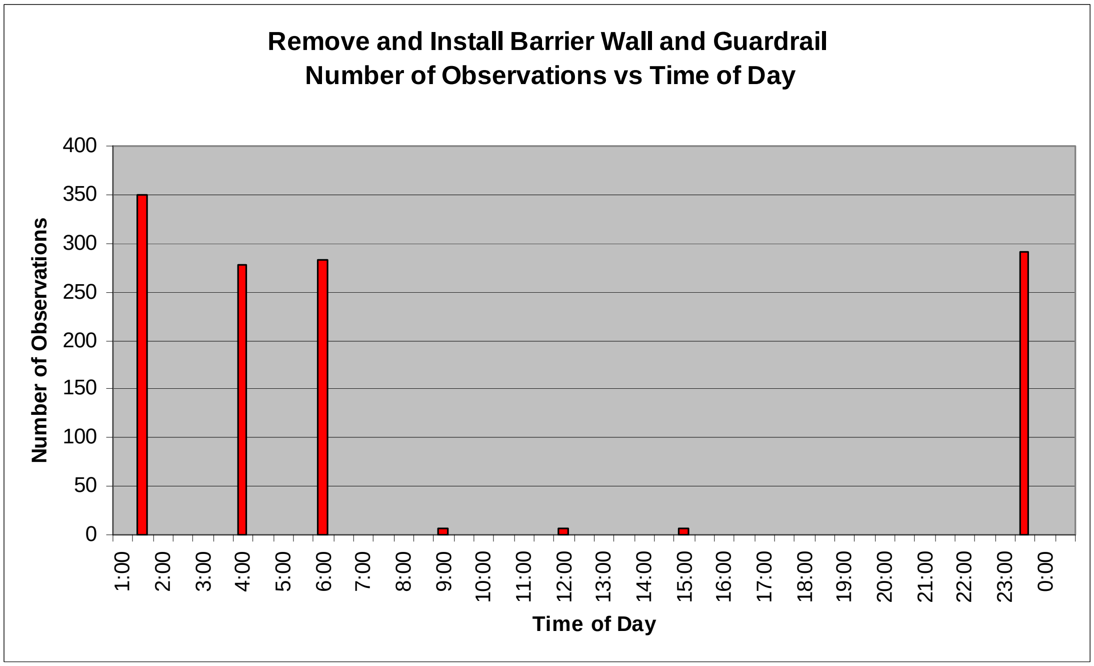

Figure 5-27 Remove and install barrier wall and guardrail observations versus time of day

5.4 Model Discussions

5.4.1 During Construction Models

This next section discusses the impacts to speed, occupancy, and volume during construction. The analysis discussion was divided into the four time categories representing the time of day of the expected traffic patterns.

This chapter includes the R-Squared values in the models. The R-squared value shows how the dependent variable is a function of the independent variables. It shows the relations of the variations. For example, an R-Squared value of 0.116 shows that 11.6% of the variation can be explained by the independent variables. The remaining 89.4% can be attributed to the random errors. In this thesis, continuous variables are not used and the majority of the predictors or independent variables are binary, so low values of R-Squared can be anticipated. The values of R-

Squared range from 0.0421 for volume at night during construction to 0.5219 for volume during afternoon off peak hours before construction.

The speed intercepts are high in the tables in this chapter. First of all they are higher, because the speed values are high, or at least higher compared to occupancy and flow. Secondly, because the analysis is forcing a linear relationship that may not be linear, thus also causing a low R-squared value.

5.4.1.1 Speed During Construction

The LRM model for speed for night time work during construction is seen in Table 5-1. The highest impact of the roadway geometric variables was during construction, where the impacts were amplified. Each of the day time construction activities (the 4 binary variables) were compared to the impact from the guardrail installation and barrier wall removal and placement (the base case). The construction variable ITS work and installing loops were not incorporated into the day time models because there were not sufficient data points. The construction variables that had an increase in speed were the pond excavation, digging ditches, earthwork, stabilization base, and drainage activities. The construction variables that had a decrease in speed were the paving activities. The second category or group of variables were the straight roadway sections or curved roadway sections. The base case was the curved roadway section and the straight roadway section was the binary variable. There was no significant difference between curved roadway segments and straight roadway segments. The last category was the median type. The median with barrier wall was the base case and the binary variables were the grass median and grass median with barrier wall. The areas with a grass median with guardrail had more of an increase in speed than areas with a grass median and areas with a median with barrier wall. The remaining variables discussed were the interval variables. As the number of ramps increased, the speed decreased. The off and on ramps also had a decrease in speed. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps.

Table 5-10 LRM model for speed during construction for night work

Parameter	Estimate	Pr > |t|	ranking of impact
Intercept	63.3027	<.0001	
Stabilization base and drainage work	3.2278	0.0181	3
Pond excavation, digging ditches, and earthwork	5.4910	0.0110	1
Pile driving, bridge demolition, and bridge deck work	-2.0146	0.1434	
Paving	-4.6690	<.0001	2
Guardrail and barrier wall	0.0000	.	4
Straight roadway segment	0.7310	0.8108	
Curved roadway segment	0.0000	.	
Number of Ramps	-3.0563	<.0001	
Grassed median	6.0199	0.0004	2
Grassed median with guardrail	7.4593	0.0004	1
Median with barrier wall	0.0000	.	3
Upstream on ramp	-4.3966	<.0001	
Upstream off ramp	-2.2467	0.0007	
Downstream on ramp	-2.0193	0.0012	
Downstream off ramp	-5.6710	<.0001	
R-Squared = 0.116170			

The LRM model for speed for work during the peak morning hours is seen in Table 5-2. The only construction variable that impacted the speed was the paving operations. Paving operations had a decrease in speed. The remainder of the construction variables were insignificant. All of the construction activities were compared to the base case of guardrail installation and barrier wall installation and removal**.** The variable ITS work and loop installation were not included in the model due to insufficient data points. There was no significant difference between curved roadway segments and straight roadway segments. As the number of ramps increased, the speed decreased. The areas with a grass median with guardrail had more of an increase in speed than areas with a grass median and areas with a median wall with barrier. The upstream on ramps, downstream on ramps, and downstream on ramps also had a decreased in speed. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps. The upstream on ramp was insignificant.

Table 5-11 LRM model for speed during construction for the morning peak hours

Parameter	**Estimate**	**Pr > |t|**	**Ranking of impact**
Intercept	66.2605	<.0001	
Stabilization base and drainage work	-0.4430	0.8459	
Pond excavation, digging ditches, and earthwork	4.6790	0.1858	
Pile driving, bridge demolition, and bridge deck work	-1.7950	0.4403	
Paving	-5.2268	0.0019	1
Guardrail and barrier wall	0.0000	.	2
Straight roadway segments	-1.4841	0.7742	
Curved roadway segments	0.0000	.	
Number of ramps	-2.6313	0.0156	
Grass median	5.2356	0.0630	2
Grass median with guardrail	5.8386	0.1019	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-4.1266	0.0004	
Upstream off ramps	-1.6988	0.1161	
Downstream on ramps	-2.3962	0.0192	
Downstream off ramps	-4.5296	0.0006	
R-Squared = 0.123809			

The LRM model for speed during construction for the morning/ early afternoon off peak hours is seen in Table 5-3. The speed increased the most when the ITS and installing loop activities were taking place. The second highest impact was during the pond excavation, digging ditches, and earthwork. The base case was the pile driving, bridge demolition, and bridge deck work. The variables paving and guardrail and barrier wall were not included in the analysis due to a lack of data. The areas with a grass median with guardrail had a decrease in speed. The speed increased in the areas with a grass median. There was no significant difference between curved roadway segments and straight roadway segments. As the number of ramps increased, the speed decreased. The downstream off ramps and upstream on ramps also had a decrease in speed. The speed had an increase in the areas with downstream on ramps. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The impact at the upstream off ramp speed was insignificant.

Table 5-12 LRM model for speed during construction for the morning/ early afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	44.4043	<.0001	
ITS work and installing loops	6.0358	0.0077	1
Stabilization base and drainage work	0.6898	0.5484	
Pond excavation, digging ditches, and earthwork	3.1979	0.0145	2
Pile driving, bridge demolition, and bridge deck work	0.0000	.	3
Straight roadway segments	3.4508	0.3358	
Curved roadway segments	0.0000	.	
Number of ramps	-3.5133	<.0001	
Grass median	5.3251	0.0035	2
Grass median with guardrail	-6.0993	0.0701	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-3.8490	<.0001	
Upstream off ramps	-0.5727	0.4279	
Downstream on ramps	3.5086	<.0001	
Downstream off ramps	-2.4830	0.0029	
R-Squared = 0.179312			

The LRM model for speed during construction for the afternoon off peak hours is seen in Table 5-4. None of the construction variables significantly impacted the speed. The base case was the pile driving, bridge demolition, and bridge deck work. The variables paving and guardrail installation and barrier wall removal and installation were not included in the model. The areas with straight roadway segments increased the speed compared to curved roadway segments. As the number of ramps increased, the speed decreased. The areas with a grass median with guardrail had more of an increase in speed than areas with a grass median only and the areas with a median with barrier wall. The upstream on ramps had a decrease in speed and the downstream on ramps had an increase in speed. The impact from the upstream off ramps and downstream off ramps had insignificant speed differences.

Table 5-13 LRM model for speed during construction for the afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	37.2244	<.0001	
ITS work and installing loops	2.7606	0.3464	
Stabilization base and drainage work	0.9821	0.5091	
Pond excavation, digging ditches, and earthwork	0.9613	0.5772	
Pile driving, bridge demolition, and bridge deck work	0.0000	.	
Straight roadway segments	10.3362	0.0346	1
Curved roadway segments	0.0000	.	2
Number of ramps	-2.4599	0.0114	
Grass median	6.6546	0.0050	2
Grass median with guardrail	10.3491	0.0160	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-4.3137	<.0001	
Upstream off ramps	0.2123	0.8222	
Downstream on ramps	2.5406	0.0052	
Downstream off ramps	-1.7098	0.1199	
R-Squared = 0.170356			

5.4.1.2 Occupancy During Construction

The LRM model for occupancy during construction for the night time traffic is seen in Table 5-5. The construction variables had an increase in occupancy were the paving activities and the bridge work activities. The highest impact was during the paving activities. The next highest impact was during the bridge work. The base case was the guardrail installation and barrier wall installation and removal. The variables ITS work and installing loops was not included in the model. There was no significant difference between curved roadway segments and straight roadway segments. As the number of ramps increased, the occupancy increased. The areas with a grass median with guardrail had more of a decrease in occupancy than areas with a grass median and areas with a median barrier wall. The off and on ramps also had an increase in occupancy. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps.

Table 5-14 LRM model for occupancy during construction for the night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	-2.5539	0.3167	
Stabilization base and drainage work	0.4334	0.7054	
Pond excavation, digging ditches, and earthwork	0.9691	0.5926	
Pile driving, bridge demolition, and bridge deck work	3.5823	0.0020	2
Paving	5.5306	<.0001	1
Guardrail and barrier wall	0.0000	.	3
Straight roadway segments	-2.9418	0.2518	
Curved roadway segments	0.0000	.	
Number of ramps	1.3226	0.0142	
Grass median	-6.1375	<.0001	2
Grass median with guardrail	-6.2671	0.0004	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	3.4318	<.0001	
Upstream off ramps	3.0515	<.0001	
Downstream on ramps	1.8412	0.0005	
Downstream off ramps	5.1314	<.0001	
R-Squared = 0.113125			

The LRM model for occupancy during construction for the morning peak hours is seen in Table 5-6. The construction variables that had an increase in occupancy were the paving activities. The base case was the guardrail installation and barrier wall installation and removal. The construction variable ITS work and installing loops was not included in the model. There was no significant difference between curved roadway segments and straight roadway segments. The number of ramps was insignificant. The areas with a grass median with guardrail and areas with a grass median only had more of a decrease in occupancy than and the areas with a median with barrier wall. The off and on ramps also had an increase in occupancy. The greatest impact was at the downstream off ramps. The least impact was at the upstream off ramps. The impact from the downstream on ramps had insignificant occupancy differences.

Table 5-15 LRM model for occupancy during construction for the morning peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	2.5500	0.5287	
Stabilization base and drainage work	1.9952	0.2671	
Pond excavation, digging ditches, and earthwork	-0.8357	0.7640	
Pile driving, bridge demolition, and bridge deck work	2.3105	0.2079	
Paving	4.8046	0.0003	1
Guardrail and barrier wall	0.0000	.	2
Straight roadway segments	-1.9639	0.6301	
Curved roadway segments	0.0000	.	
Number of ramps	0.1752	0.8374	
Grass median	-6.6797	0.0027	2
Grass median with guardrail	-6.4435	0.0223	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	2.8747	0.0017	
Upstream off ramps	1.5950	0.0615	
Downstream on ramps	0.8832	0.2715	
Downstream off ramps	3.5566	0.0006	
R-Squared = 0.098387			

The LRM model for occupancy during construction for the morning/ early afternoon off peak hours is seen in Table 5-7. The construction variable stabilization base and drainage work was the only variable with a significant impact. The base case was pile driving, bridge demolition, and bridge deck work. The variables paving and guardrail installation and barrier wall removal and installation were not included in the model. There was no significant difference between curved roadway segments and straight roadway segments. The number of ramps was insignificant. The areas with a grass median with guardrail had more of an increase in occupancy than areas with a median barrier wall. The grass median had a decrease in occupancy compared to the impact of a median with barrier wall. The downstream off ramps and upstream on ramps had an increase in occupancy. The downstream on ramps had a decrease in occupancy. The greatest impact was at the upstream on ramps. The least impact was at the downstream off ramps. The impact of the upstream off ramps had insignificant occupancy differences.

Table 5-16 LRM model for occupancy during construction for the morning/ early afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	16.3096	<.0001	
ITS work and installing loops	-1.4375	0.3718	
Stabilization base and drainage work	2.6139	0.0014	1
Pond excavation, digging ditches, and earthwork	0.1290	0.8897	
Pile driving, bridge demolition, and bridge deck work	0.0000	.	2
Straight roadway segments	-1.8956	0.4572	
Curved roadway segments	0.0000	.	
Number of ramps	-0.2297	0.6660	
Grass median	-3.8180	0.0032	2
Grass median with guardrail	5.0002	0.0368	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	2.9548	<.0001	
Upstream off ramps	0.5024	0.3282	
Downstream on ramps	-2.1894	<.0001	
Downstream off ramps	1.9370	0.0011	
R-Squared = 0.088175			

The LRM model for occupancy during construction for the afternoon off peak hours is shown in Table 5-8. The construction variables were all insignificant. The base case was pile driving, bridge demolition, and bridge deck work. The variables paving, guardrail installation, and barrier wall removal and installation were not included in the model. There was no significant difference between curved roadway segments and straight roadway segments. The number of ramps was insignificant. The areas with a grass median with guardrail had more of a decrease in occupancy than areas with a grass median only and a median with barrier wall. The upstream on ramps had an increase in occupancy. The impacts from the other ramps had insignificant occupancy differences.

Table 5-17 LRM model for occupancy during construction for the afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	22.0993	<.0001	
ITS work and installing loops	1.2584	0.5542	
Stabilization base and drainage work	1.5832	0.1428	
Pond excavation, digging ditches, and earthwork	1.2500	0.3181	
Pile driving, bridge demolition, and bridge deck work	0.0000	.	
Straight roadway segments	-5.3306	0.1329	
Curved roadway segments	0.0000	.	
Number of ramps	-1.1725	0.0960	
Grass median	-6.8699	<.0001	2
Grass median with guardrail	-8.9459	0.0042	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	3.0985	<.0001	
Upstream off ramps	0.1503	0.8265	
Downstream on ramps	-1.0385	0.1151	
Downstream off ramps	1.1001	0.1680	
R-Squared = 0.060728			

5.4.1.3 Volume During Construction

The LRM model for volume during construction for the night time hours is seen in Table 5-9. The stabilization and limerock base and drainage work and paving activities had an increase in volume. The highest impact was during the stabilization and drainage work. The remainder of the construction variables were insignificant when compared to the base case of the guardrail installation and barrier wall installation and removal. The variable ITS work and installing loops were not included in the model. There was no significant difference between the straight roadway segments and the curved roadway segments. The number of ramps was insignificant. The type of median wall was insignificant to the volume at night. The upstream off ramps had an increase in volume. The upstream on ramps, downstream on ramps, and downstream off ramps were insignificant.

Table 5-18 LRM model for volume during construction for the night time hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	4.2445	<.0001	
Stabilization base and drainage work	1.0049	0.0006	1
Pond excavation, digging ditches, and earthwork	0.2851	0.5375	
Pile driving, bridge demolition, and bridge deck work	0.3107	0.2927	
Paving	0.3688	0.0971	2
Guardrail and barrier wall	0.0000	.	3
Straight roadway segments	-0.5588	0.3937	
Curved roadway segments	0.0000	.	
Number of ramps	0.1303	0.3435	
Grass median	-0.0487	0.8929	
Grass median with guardrail	-0.4056	0.3695	
Median with barrier wall	0.0000	.	
Upstream on ramps	-0.1245	0.4092	
Upstream off ramps	0.4070	0.0043	
Downstream on ramps	0.2134	0.1104	
Downstream off ramps	0.1153	0.4939	
R-Squared = 0.042103			

The LRM model for volume during construction for the morning peak hours is seen in Table 5-10. The stabilization and limerock base and drainage work had an increase in volume. The remainder of the construction variables were insignificant when compared to the base case of guardrail installation and barrier wall installation and removal. The ITS work and installing loops were not included in the analysis. The straight roadway segments decreased the volume. The number of ramps was insignificant. The grass median with guardrail had an increase in volume compared to a median with barrier wall. The grass median parameter was insignificant. The upstream on ramps had a decrease in volume. The impacts from the other ramps were insignificant.

Table 5-19 LRM model for volume during construction for the morning peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	8.8450	<.0001	
Stabilization base and drainage work	0.9645	0.0120	1
Pond excavation, digging ditches, and earthwork	-0.8845	0.1355	
Pile driving, bridge demolition, and bridge deck work	-0.0812	0.8348	
Paving	0.2757	0.3239	
Guardrail and barrier wall	0.0000	.	2
Straight roadway segments	-2.9499	0.0007	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.0163	0.9285	
Grass median	0.2440	0.6040	
Grass median with guardrail	1.3334	0.0260	1
Median with barrier wall	0.0000	.	2
Upstream on ramps	-0.5550	0.0043	
Upstream off ramps	0.1330	0.4621	
Downstream on ramps	-0.1874	0.2723	
Downstream off ramps	-0.3184	0.1465	
R-Squared = 0.135803			

The LRM model for volume during construction for the morning/ early afternoon off peak hours is seen in Table 5-11. The construction variables stabilization and limerock base, drainage work, pond excavation, digging ditches, and earthwork had an increase in volume. The base case was pile driving, bridge demolition, and bridge deck work. The variables paving and guardrail installation and barrier wall removal and installation were not included in the model. There was a significant difference between the straight roadway section and the curved roadway section. The straight roadway segments had a decrease in volume. There was a significant difference with the number of ramps in the area. As the number of ramps increased, the volume decreased. There was no significant difference in areas with a grass median with guardrail, the areas with a grass median only, and the areas with a concrete barrier wall. The downstream off and on ramps had a decrease in volume. The largest impact was at the downstream off ramps and the least impact was at the downstream on ramps. The impact from the upstream off and on ramps had insignificant volume differences.

Table 5-20 LRM model for volume during construction for the morning/ early afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	18.4235	<.0001	
ITS work and installing loops	-0.3361	0.4732	
Stabilization base and drainage work	1.2308	<.0001	1
Pond excavation, digging ditches, and earthwork	0.6812	0.0120	2
Pile driving, bridge demolition, and bridge deck work	0.0000	.	3
Straight roadway segment	-5.4839	<.0001	1
Curved roadway segment	0.0000	.	2
Number of Ramps	-0.7740	<.0001	
Grassed median	-0.1123	0.7660	
Grassed median with guardrail	0.6562	0.3466	
Median with barrier wall	0.0000	.	
Upstream on ramp	-0.1619	0.2765	
Upstream off ramp	0.0100	0.9468	
Downstream on ramp	-0.2570	0.0725	
Downstream off ramp	-0.7606	<.0001	
R-Squared = 0.103116			

The LRM model for volume during construction for the afternoon off peak hours is seen in Table 5-12. The construction variables were all insignificant. The base case was pile driving, bridge demolition, and bridge deck work. The variables paving and guardrail installation and barrier wall removal and installation were not included in the model. There was no significant difference between the areas with straight roadway segments and curved roadway segments. As the number of ramps at the loop detector increased, the volume decreased. The areas with a grass median with guardrail had the highest impact of a decrease in volume. The areas with a grass median only also had a decrease in volume. The upstream on ramps had an increase in volume. The impact from the upstream off ramps, downstream on ramps, and downstream off ramps had no significant volume differences.

Table 5-21 LRM model for volume during construction for the afternoon off peak hours

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	22.0993	<.0001	1
ITS work and installing loops	1.2584	0.5542	
Stabilization base and drainage work	1.5832	0.1428	
Pond excavation, digging ditches, and earthwork	1.2500	0.3181	
Pile driving, bridge demolition, and bridge deck work	0.0000	.	2
Straight roadway segments	-5.3306	0.1329	
Curved roadway segments	0.0000	.	
Number of ramps	-1.1725	0.0960	
Grass median	-6.8699	<.0001	2
Grass median with guardrail	-8.9459	0.0042	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	3.0985	<.0001	
Upstream off ramps	0.1503	0.8265	
Downstream on ramps	-1.0385	0.1151	
Downstream off ramps	1.1001	0.1680	
R-Squared = 0.097474			

5.4.2 Before Construction Models

5.4.2.1 Speed Before Construction

The LRM model for speed for night time traffic before construction is seen in Table 5-13. The straight roadway segments increased the speed. The number of ramps was insignificant. The areas with a grass median alone had more of an increase in speed than areas with a grass median with guardrail and a median with barrier wall. The off and on ramps also had a decrease in speed. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps.

Table 5-22 LRM model for speed before construction for night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	55.0285	<.0001	
Straight roadway segments	5.6179	0.0619	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.2595	0.5554	
Grass median	6.4483	<.0001	1
Grass median with guardrail	5.9207	<.0001	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-2.8822	<.0001	
Upstream off ramps	-1.8111	<.0001	
Downstream on ramps	-0.8163	0.0609	
Downstream off ramps	-2.4393	<.0001	
R-Squared = 0.074178			

The LRM model for speed for morning peak traffic before construction is seen in Table 5-14. There was no significant difference between curved roadway segments and straight roadway segments. The number of ramps was insignificant. The areas with grass median had more of an increase in speed than areas with a grass median with guardrail and a median with barrier wall.

The upstream on ramps, upstream off ramps, and downstream off ramps also had a decrease in speed. The greatest impact was at the upstream on ramps. The least impact was at the downstream off ramps. The downstream on ramp had insignificant speed differences.

Table 5-23 LRM model for speed before construction for morning peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	59.9095	<.0001	
Straight roadway segments	0.1787	0.9659	
Curved roadway segments	0.0000	.	
Number of ramps	0.0127	0.9845	
Grass median	7.6491	<.0001	1
Grass median with guardrail	6.2895	0.0003	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-2.5963	0.0001	
Upstream off ramps	-2.0501	0.0006	
Downstream on ramps	-0.6437	0.295	
Downstream off ramps	-1.8586	0.0046	
R-Squared = 0.123215			

The LRM model for speed for morning/ early afternoon off peak traffic before construction is seen in Table 5-15. There was no significant difference between the curved roadway segments and the straight roadway segments. As the number of ramps increased, the speed decreased. The areas with grass median with guardrail had more of a decrease in speed than areas with median with barrier wall. The grass median parameter was insignificant. The upstream on ramps, the downstream on ramps, and downstream off ramps also had an increase in speed. The greatest impact was at the downstream on ramps. The least impact was at the upstream on ramps. The upstream off ramps had insignificant speed differences.

Table 5-24 LRM model for speed before construction for morning/ early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	49.3867	<.0001	
Straight roadway segments	-2.7885	0.3573	
Curved roadway segments	0.0000	.	
Number of ramps	-1.7588	0.0004	
Grass median	1.0249	0.4054	
Grass median with guardrail	-9.7186	<.0001	1
Median with barrier wall	0.0000	.	2
Upstream on ramps	1.1332	0.0373	
Upstream off ramps	-0.0527	0.9085	
Downstream on ramps	3.7629	<.0001	
Downstream off ramps	2.2088	0.0002	
R-Squared = 0.155552			

The LRM model for speed for afternoon off peak traffic before construction is seen in Table 5-16. There was no significant difference between curved roadway segments and straight roadway segments. As the number of ramps increased, the speed decreased. The areas with a grass median with guardrail had a greater increase in speed than areas with a grass median and areas with a median barrier wall. The downstream off and on ramps also had an increase in speed. The greatest impact was at the downstream on ramps. The least impact was at the downstream off ramps. The upstream off and on ramps had insignificant speed differences.

Table 5-25 LRM model for speed before construction for afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	46.3351	<.0001	
Straight roadway segments	1.4585	0.6367	
Curved roadway segments	0.0000	.	
Number of ramps	-1.6313	0.0023	
Grass median	2.6612	0.041	2
Grass median with guardrail	7.6490	0.001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	0.4099	0.4831	
Upstream off ramps	-0.2281	0.6348	
Downstream on ramps	2.9938	<.0001	
Downstream off ramps	2.5778	<.0001	
R-Squared = 0.219200			

5.4.2.2 Occupancy Before Construction

The LRM model for occupancy for night time traffic before construction is seen in Table 5-17. The straight roadway segments decreased the occupancy. The number of ramps was insignificant. The areas with a grass median with guardrail had more of a decrease in occupancy than areas with a grass median and a median with barrier wall. The upstream off and on ramps and the down steam off ramps had an increase in occupancy. The greatest impact was from downstream off ramps. The least impact was from the upstream on ramps. The downstream on ramps had insignificant occupancy differences.

Table 5-26 LRM model for occupancy before construction for night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	4.9082	0.0024	
Straight roadway segments	-2.7483	0.0769	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.1518	0.504	
Grass median	-3.0095	<.0001	2
Grass median with guardrail	-4.5198	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	1.1186	<.0001	
Upstream off ramps	1.3813	<.0001	
Downstream on ramps	0.2555	0.2556	
Downstream off ramps	1.5518	<.0001	
R-Squared = 0.108444			

The LRM model for occupancy for morning peak traffic before construction is seen in Table 5-18. There was no significant difference between the straight roadway segments and the curved roadway segments. The number of ramps was insignificant. The areas with a grass median with guardrail had less of an impact in occupancy than areas with a median with barrier wall. The areas with a grass median were insignificant. The upstream off ramps also had an increase in occupancy. The impacts from the other ramps had insignificant occupancy differences.

Table 5-27 LRM model for occupancy before construction for morning peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	7.5219	0.0001	
Straight roadway segments	-2.1290	0.2525	
Curved roadway segments	0.0000	.	
Number of ramps	-0.2047	0.4805	
Grass median	-1.1357	0.0887	
Grass median with guardrail	-2.2978	0.0031	1
Median with barrier wall	0.0000	.	2
Upstream on ramps	-0.2463	0.4049	
Upstream off ramps	1.1371	<.0001	
Downstream on ramps	-0.3333	0.2231	
Downstream off ramps	0.0148	0.9593	
R-Squared = 0.116177			

The LRM model for occupancy for morning/ early afternoon off peak traffic before construction is seen in Table 5-19. There was no significant difference between straight roadway segments and the curved roadway segments. The number of ramps was insignificant. The areas with grass median with guardrail had more of an increase in occupancy than areas with median with barrier wall. The areas with a grass median decreased the occupancy. The upstream on ramps and the downstream off and on ramps had a decrease in occupancy. The greatest impact was at the upstream on ramps. The least impact was at the downstream off ramps. The upstream off ramps had insignificant occupancy differences.

Table 5-28 LRM model for occupancy before construction for morning/ early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	14.1208	<.0001	
Straight roadway segments	1.1032	0.5174	
Curved roadway segments	0.0000	.	
Number of ramps	0.1247	0.6563	
Grass median	-2.1106	0.0024	2
Grass median with guardrail	8.8257	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.1798	0.0001	
Upstream off ramps	-0.3321	0.1976	
Downstream on ramps	-0.9340	0.001	
Downstream off ramps	-0.7742	0.0214	
R-Squared = 0.153161			

The LRM model for occupancy for the afternoon off peak traffic before construction is seen in Table 5-20. There was no significant difference between straight roadway segments and the curved roadway segments. The number of ramps was insignificant. The areas with a grass median with guardrail and only a grass median had more of a decrease in occupancy than areas with a median with barrier wall. The downstream off ramps and upstream on ramps also had a decrease in occupancy. The greatest impact was at the downstream off ramps. The least impact was at the upstream on ramps. The upstream off ramps and downstream on ramps had insignificant occupancy differences.

Table 5-29 LRM model for occupancy before construction for afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	14.3630	<.0001	
Straight roadway segments	0.3823	0.8035	
Curved roadway segments	0.0000	.	
Number of ramps	-0.0522	0.844	
Grass median	-3.2877	<.0001	1
Grass median with guardrail	-3.0240	0.0089	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-0.7674	0.0084	
Upstream off ramps	-0.1651	0.4897	
Downstream on ramps	-0.3651	0.1791	
Downstream off ramps	-0.9043	0.0048	
R-Squared = 0.184201			

5.4.2.3 Volume Before Construction

The LRM model for volume for night time traffic before construction is seen in Table 5-21. There was no significant difference between straight roadway segments and the curved roadway segments. The number of ramps was insignificant. The areas with grass median with guardrail and grass median had more of a decrease in volume than areas with a median with barrier wall. The downstream on and off ramps and upstream on ramps had an increase in volume. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The upstream on ramps had no significant volume differences

Table 5-30 LRM model for volume before construction for night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	4.5796	<.0001	
Straight roadway segments	0.3827	0.6955	
Curved roadway segments	0.0000	.	
Number of ramps	-0.1914	0.1815	
Grass median	-1.5150	<.0001	2
Grass median with guardrail	-2.7670	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-0.0731	0.626	
Upstream off ramps	0.5638	<.0001	
Downstream on ramps	0.3065	0.0305	
Downstream off ramps	0.3378	0.0201	
R-Squared = 0.090071			

The LRM model for volume for peak morning traffic before construction is seen in Table 5-22. There was no significant difference between straight roadway segments and the curved roadway segments, the number of ramps, and the type of median. The only ramp parameter that had a significant impact was the upstream on ramps; it had a decrease in volume.

Table 5-31 LRM model for volume before construction for peak morning traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	11.4691	<.0001	
Straight roadway segments	-2.5851	0.1439	
Curved roadway segments	0.0000	.	
Number of ramps	-0.3702	0.1796	
Grass median	-0.6075	0.3368	
Grass median with guardrail	-0.8051	0.2718	
Median with barrier wall	0.0000	.	
Upstream on ramps	-1.0860	0.0001	
Upstream off ramps	0.0450	0.8568	
Downstream on ramps	-0.2387	0.3579	
Downstream off ramps	-0.5112	0.0641	
R-Squared = 0.124704			

The LRM model for volume for morning/ early afternoon off peak traffic before construction is seen in Table 5-23. The straight roadway segments decreased the occupancy. As the number of ramps in the area increased, the volume decreased. The areas with a grass median had more of a decrease in volume than areas with a grass median with guardrail and a median with barrier wall. The downstream off and on ramps and upstream on ramps had a decrease in volume. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The impacts from the upstream off ramps had insignificant volume differences.

Table 5-32 LRM model for volume before construction for morning/ early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	18.9053	<.0001	
Straight roadway segments	-1.5768	0.0034	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.3623	<.0001	
Grass median	-1.6428	<.0001	1
Grass median with guardrail	-0.6164	0.1042	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.3436	<.0001	
Upstream off ramps	-0.1067	0.1888	
Downstream on ramps	-0.8127	<.0001	
Downstream off ramps	-0.8771	<.0001	
R-Squared = 0.412600			

The LRM model for volume for off peak afternoon traffic before construction is seen in Table 5-24. The straight roadway segments decreased the volume. The number of ramps was insignificant. The areas with a grass median had more of a decrease in volume than areas with a grass median with guardrail and a median with barrier wall. The downstream on and off ramps and upstream on ramps had a decrease in volume. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The impacts from the upstream off ramps had insignificant volume differences.

Table 5-33 LRM model for volume before construction for afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	18.7135	<.0001	
Straight roadway segments	-1.8145	0.0017	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.0023	0.9814	
Grass median	-1.2612	<.0001	1
Grass median with guardrail	-0.7422	0.0872	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.4396	<.0001	
Upstream off ramps	-0.1271	0.1573	
Downstream on ramps	-0.4887	<.0001	
Downstream off ramps	-1.2631	<.0001	
R-Squared = 0.512994			

5.4.3 After Construction Models

5.4.3.1 Speed After Construction

The LRM model for speed for night time traffic after construction is seen in Table 5-25. The straight roadway segments increased the speed. The number of ramps was insignificant. The areas with grass median had more of an increase in speed than areas with a grass median with guardrail and a median with barrier wall. The downstream off and on ramps and upstream on ramps had a decrease in speed. The greatest impact was at the downstream off ramps. The least impact was at the upstream on ramps. The upstream off ramps had insignificant speed differences.

Table 5-34 LRM model for speed after construction for night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	44.9454	<.0001	
Straight roadway segments	7.7819	<.0001	1
Curved roadway segments	0.0000	.	2
Number of ramps	-0.1547	0.6341	
Grass median	7.8087	<.0001	1
Grass median with guardrail	5.6159	<.0001	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.1100	0.0012	
Upstream off ramps	-0.1921	0.5702	
Downstream on ramps	-1.1893	0.0004	
Downstream off ramps	-1.5126	<.0001	
R-Squared = 0.167787			

The LRM model for speed for morning peak traffic after construction is seen in Table 5-26. The straight roadway segments increased speed. The number of ramps was insignificant. The areas with a grass median had more of an increase in speed than areas with a grass median with guardrail and the areas with a median with barrier wall. The downstream off and on ramps and upstream on ramps had a decrease in speed. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The impact from the upstream off ramps was insignificant.

Table 5-35 LRM model for speed after construction for morning peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	44.9349	<.0001	
Straight roadway segments	9.1542	<.0001	1
Curved roadway segments	0.0000	.	2
Number of ramps	0.3718	0.3688	
Grass median	6.7914	<.0001	1
Grass median with guardrail	4.1418	0.0002	2
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.3126	0.0019	
Upstream off ramps	-0.0796	0.8488	
Downstream on ramps	-0.7372	0.0708	
Downstream off ramps	-1.0199	0.0226	
R-Squared = 0.228351			

The LRM model for speed for morning/ early afternoon off peak traffic after construction is seen in Table 5-27. There was no significant difference between straight roadway segments and the curved roadway segments. As the number of ramps increased, the speed decreased. The areas with a grass median with guardrail had more of a decrease in speed than areas with a median with barrier wall. The grass median increased the speed. The downstream off and on ramps and upstream on ramps had an increase in speed. The greatest impact was at the downstream on ramps. The least impact was at the upstream on ramps. The impact from the upstream off ramps was insignificant.

Table 5-36 LRM model for speed after construction for morning/ early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	40.9768	<.0001	
Straight roadway segments	1.9559	0.4292	
Curved roadway segments	0.0000	.	
Number of ramps	-2.3725	<.0001	
Grass median	2.4598	0.0461	2
Grass median with guardrail	-7.2534	0.0016	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	2.1596	<.0001	
Upstream off ramps	-0.4810	0.2792	
Downstream on ramps	4.2111	<.0001	
Downstream off ramps	3.9940	<.0001	
R-Squared = 0.233242			

The LRM model for speed for the afternoon off peak traffic after construction is seen in Table 5-28. The straight roadway segments increased the speed. As the number of ramps increased, the speed decreased. The areas with a grass median with guardrail and the areas with a grass median only had more of an increase in speed than areas with a median with barrier wall. The downstream off and on ramps had an increase in speed. The greatest impact was at the downstream on ramps. The least impact was at the downstream off ramps. The upstream off and on ramps had insignificant speed differences.

Table 5-37 LRM model for speed after construction for afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	38.5698	<.0001	
Straight roadway segments	8.3891	0.0024	1
Curved roadway segments	0.0000	.	2
Number of ramps	-1.4421	0.0237	
Grass median	6.9569	<.0001	2
Grass median with guardrail	8.4615	0.001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-0.2063	0.7366	
Upstream off ramps	-0.7533	0.136	
Downstream on ramps	1.6497	0.0123	
Downstream off ramps	1.2157	0.0822	
R-Squared = 0.238413			

5.4.3.2 Occupancy After Construction

The LRM model for occupancy for night time traffic after construction is seen in Table 5-29. There were no parameters which significantly impacted the night time occupancy after construction.

The LRM model for occupancy for morning peak traffic after construction is seen in Table 5-30. The straight roadway segments had a decrease in occupancy. The number of ramps by the loop detector did not have a significant impact. The areas with a grass median with guardrail and areas with a grass median only had more of an increase in occupancy than areas with a median with barrier wall. The upstream off and on ramps also had a decrease in occupancy. The greatest impact was at the upstream on ramps. The least impact was at the upstream off ramps. The downstream off and on ramps had insignificant occupancy differences.

Table 5-38 LRM model for occupancy after construction for night time traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	4.5057	0.0004	
Straight roadway segments	-0.6491	0.5933	
Curved roadway segments	0.0000	.	
Number of ramps	0.3709	0.1015	
Grass median	-0.3993	0.4468	
Grass median with guardrail	-0.5305	0.3849	
Median with barrier wall	0.0000	.	
Upstream on ramps	-0.2495	0.2945	
Upstream off ramps	-0.2883	0.2212	
Downstream on ramps	0.3592	0.1227	
Downstream off ramps	-0.2267	0.3595	
R-Squared = 0.022386			

Table 5-39 LRM model for occupancy after construction for the morning peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	7.7761	<.0001	
Straight roadway segments	-3.9342	<.0001	2
Curved roadway segments	0.0000	.	1
Number of ramps	0.2089	0.1607	
Grass median	0.6958	0.042	2
Grass median with guardrail	1.2547	0.0014	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-0.4792	0.0016	
Upstream off ramps	-0.3787	0.0121	
Downstream on ramps	-0.0123	0.9329	
Downstream off ramps	-0.2245	0.1617	
R-Squared = 0.136017			

The LRM model for occupancy for morning/ early afternoon off peak traffic after construction is seen in Table 5-31. The straight roadway segments decreased the occupancy. As the number of ramps in the area increased, the occupancy increased. The areas with a grass median with guardrail and areas with a grass median only had more of an increase in occupancy than areas with a median with barrier wall. The downstream off and on ramps and upstream on ramps had a decrease in occupancy. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps. The impact from the upstream off ramps was insignificant.

Table 5-40 LRM model for occupancy after construction for the morning/ early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	20.7162	<.0001	
Straight roadway segments	-3.4638	0.0529	1
Curved roadway segments	0.0000	.	2
Number of ramps	2.2798	<.0001	
Grass median	3.4079	0.0001	2
Grass median with guardrail	7.0521	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-4.0573	<.0001	
Upstream off ramps	-0.2581	0.4219	
Downstream on ramps	-2.9863	<.0001	
Downstream off ramps	-4.6638	<.0001	
R-Squared = 0.229043			

The LRM model for occupancy for the afternoon off peak traffic after construction is seen in Table 5-32. The straight roadway segments decreased the occupancy. As the number of ramps in the area increased, the occupancy increased. The areas with a grass median had more of an increase in occupancy than areas with a median with barrier wall. The grass median with guardrail had no significant impact. The downstream off and on ramps and upstream on ramps had a decrease in occupancy. The greatest impact was at the upstream on ramps. The least impact was at the downstream on ramps. The impact from the upstream off ramps had insignificant occupancy differences.

Table 5-41 LRM model for occupancy after construction for the afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	22.5091	<.0001	
Straight roadway segments	-9.0969	<.0001	1
Curved roadway segments	0.0000	.	2
Number of ramps	2.0368	<.0001	
Grass median	2.3247	0.0221	1
Grass median with guardrail	1.9260	0.3016	
Median with barrier wall	0.0000	.	2
Upstream on ramps	-2.7848	<.0001	
Upstream off ramps	0.0542	0.8832	
Downstream on ramps	-1.4228	0.0031	
Downstream off ramps	-3.4931	<.0001	
R-Squared = 0.217476			

5.4.3.3 Volume After Construction

The LRM model for volume for night time traffic after construction is seen in Table 5-33. There was no significant difference between the straight roadway sections and the curved roadway sections and the type of median. As the number of ramps in the area increased, the volume increased. The downstream off ramps and upstream on ramps had a decrease in volume. The greatest impact was at the upstream on ramps. The least impact was at the downstream off ramps.

The impacts of upstream off ramps and downstream on ramps had insignificant volume differences.

Table 5-42 LRM model for volume after construction for night traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	3.8652	<.0001	
Straight roadway segments	0.4610	0.4744	
Curved roadway segments	0.0000	.	
Number of ramps	0.4432	0.0002	
Grass median	0.3477	0.2116	
Grass median with guardrail	-0.2312	0.4752	
Median with barrier wall	0.0000	.	
Upstream on ramps	-0.5337	<.0001	
Upstream off ramps	0.0515	0.6799	
Downstream on ramps	0.0434	0.725	
Downstream off ramps	-0.2405	0.0669	
R-Squared = 0.050345			

The LRM model for volume for the morning peak traffic after construction is seen in Table 5-34. There was no significant difference between the straight roadway sections and the curved roadway sections. There was not a significant difference with the number of ramps by the loop detector. The areas with a grass median and a grass median with guardrail had more of an increase in volume than areas with a median with barrier wall. The downstream off ramps and upstream off and on ramps also had a decrease in volume. The greatest impact was from upstream on ramps. The least impact was at the upstream off ramps. The impact at the downstream on ramps had insignificant volume differences.

Table 5-43 LRM model for volume after construction for morning peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	6.4700	<.0001	
Straight roadway segments	-0.9187	0.3011	
Curved roadway segments	0.0000	.	
Number of ramps	0.2353	0.1497	
Grass median	0.8733	0.0201	2
Grass median with guardrail	1.2749	0.0031	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-0.8749	<.0001	
Upstream off ramps	-0.3112	0.0596	
Downstream on ramps	-0.0953	0.5531	
Downstream off ramps	-0.5015	0.0046	
R-Squared = 0.116552			

The LRM model for volume for the morning/ early afternoon off peak traffic after construction is seen in Table 5-35. The straight roadway segments decreased the volume. As the number of ramps in the area increased, the volume increased. The areas with a grass median with guardrail and a grass median only had more of an increase in volume than areas with a grass median with a guardrail median with barrier wall. The downstream off and on ramps and upstream off and on ramps had a decrease in volume. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps.

Table 5-44 LRM model for volume after construction for morning / early afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	13.5811	<.0001	
Straight roadway segments	-0.9122	0.0361	1
Curved roadway segments	0.0000	.	2
Number of ramps	1.1262	<.0001	
Grass median	1.6444	<.0001	2
Grass median with guardrail	6.1532	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.1369	<.0001	
Upstream off ramps	-0.6017	<.0001	
Downstream on ramps	-0.5178	<.0001	
Downstream off ramps	-1.2760	<.0001	
R-Squared = 0.372860			

The LRM model for volume for the afternoon off peak traffic after construction is seen in Table 5-36. There was no significant difference between the straight roadway sections and the curved roadway sections. As the number of ramps in the area increased, the volume increased. The areas with a grass median with guardrail and only a grass median had more of an increase in volume than areas with a median with barrier wall. The downstream off and on ramps and upstream off and on ramps had a decrease in volume. The greatest impact was at the downstream off ramps. The least impact was at the downstream on ramps.

Table 5-45 LRM model for volume after construction for afternoon off peak traffic

Parameter	Estimate	Pr > |t|	Ranking of impact
Intercept	13.5215	<.0001	
Straight roadway segments	-0.4093	0.4508	
Curved roadway segments	0.0000	.	
Number of ramps	1.0070	<.0001	
Grass median	1.4341	<.0001	2
Grass median with guardrail	5.1100	<.0001	1
Median with barrier wall	0.0000	.	3
Upstream on ramps	-1.0435	<.0001	
Upstream off ramps	-0.7216	<.0001	
Downstream on ramps	-0.5060	<.0001	
Downstream off ramps	-1.4474	<.0001	
R-Squared = 0.447308			

5.4.4 Construction Impact Analysis of the Time Segments

5.4.4.1 Night Time Comparison of Construction Activities.

As seen in Table 5-37, the construction activities that most impacted speed at night time by slowing traffic down at night was the paving. This work involved several pieces of equipment so the traffic often slowed down to see what is taking place and look at all of the equipment. Many times this operation closed two lanes of traffic, slowing the traffic down more. It is interesting to note that the pond excavation, digging ditches, earthwork, stabilization and limerock base, and drainage work had an increase in speed at night. These activities were minimal at night and the work typically took place off the side of the road behind barrier wall, so the impact was not substantial. Bridge construction activities were minimal at night and the speed impacts were insignificant.

The construction activity that had an increase in occupancy during the night time was the paving. The bridge construction work also had an increase in occupancy at night. The bridge work at night was typically the demolition of the outside edges of the existing bridges before the widening for the bridges could begin. The bridge demolition involved large jack hammers and dust could be seen in the air from the concrete demolition. The ability of the roadway users to see the large equipment and dust from the demolition slowed the traffic down, increasing the occupancy. The pond excavation and stabilization and limerock base and drainage work impacts had no significant occupancy differences.

The construction activities that had an increase in volume during the night time were the stabilization and limerock base and drainage work. It is interesting to note that all other work activities were insignificant.

As seen in Table 5-37, overall the highest impact to the traffic operations from the night time construction activities were the paving activities. Bridge work at night also had an increase in occupancy. As can be expected, the items which decreased the speed increased the occupancy. The magnitude of the decrease in speed was similar in magnitude of increase to the occupancy. The volume had the least impact during the night time. The majority of the parameters had insignificant volume differences. The traffic is the lightest at night; therefore if a driver slows down to look at the activities there is less of an impact to drivers downstream.

Table 5-46 During construction night time comparison

	Speed			Occupancy			Volume		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	63.3027	<.0001		-2.5539	0.3167		4.2445	<.0001	
ITS work and installing loops									
Stabilization base and drainage work	3.2278	0.0181	3	0.4334	0.7054		1.0049	0.0006	1
Pond excavation, digging ditches, and earthwork	5.4910	0.0110	1	0.9691	0.5926		0.2851	0.5375	
Pile driving, bridge demolition, and bridge deck work	-2.0146	0.1434		3.5823	0.0020	2	0.3107	0.2927	
Paving	-4.6690	<.0001	2	5.5306	<.0001	1	0.3688	0.0971	
Guardrail and barrier wall	0.0000	.	4	0.0000	.	3	0.0000	.	2
Straight roadway segments	0.7310	0.8108		-2.9418	0.2518		-0.5588	0.3937	
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	
Number of ramps	-3.0563	<.0001		1.3226	0.0142		0.1303	0.3435	
Grass median	6.0199	0.0004	2	-6.1375	<.0001	2	-0.0487	0.8929	
Grass median with guardrail	7.4593	0.0004	1	-6.2671	0.0004	1	-0.4056	0.3695	
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	
Upstream on ramps	-4.3966	<.0001		3.4318	<.0001		-0.1245	0.4092	
Upstream off ramps	-2.2467	0.0007		3.0515	<.0001		0.4070	0.0043	
Downstream on ramps	-2.0193	0.0012		1.8412	0.0005		0.2134	0.1104	
Downstream off ramps	-5.6710	<.0001		5.1314	<.0001		0.1153	0.4939	
	R-Squared = 0.116170			R-Squared = 0.113125			R-Squared = 0.042103		

5.4.4.2 Morning Peak Hour Comparison

As seen in Table 5-38, the construction activities that impacted speed by slowing traffic down during the morning peak hour were paving activities. The other construction activity impacts were insignificant. This can be attributed to the fact that during the morning commute, the traffic was slowed down already by the volume of traffic during the morning rush hours and the construction did not have a large impact in slowing the traffic down.

The construction activities that had an increase in occupancy during the morning peak hours were the paving activities. The other construction activities' impacts had no significant occupancy differences.

The construction activities that had an increase in volume during morning peak hour were the stabilization and limerock base and drainage work. It is interesting to note that all other work activities had no significant volume differences.

Overall the highest impact to the traffic operations from the morning peak hour construction activities were the paving activities. Paving impacted the speed and occupancy decreasing the traffic flow, but did not significantly impact the volume. The impacts during the morning commute for other construction activities were insignificant. Due to the volume of traffic on the roadway during rush hour, the traffic is slowed down already and the activities have a minimal impact while the construction work is ongoing.

Table 5-47 During construction morning peak comparison

	Speed			Occupancy			Volume		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	66.2605	<.0001		2.5500	0.5287		8.8450	<.0001	
ITS work and installing loops									
Stabilization base and drainage work	-0.4430	0.8459		1.9952	0.2671		0.9645	0.0120	1
Pond excavation, digging ditches, and earthwork	4.6790	0.1858		-0.8357	0.7640		-0.8845	0.1355	
Pile driving, bridge demolition, and bridge deck work	-1.7950	0.4403		2.3105	0.2079		-0.0812	0.8348	
Paving	-5.2268	0.0019	1	4.8046	0.0003	1	0.2757	0.3239	
Guardrail and barrier wall	0.0000	.	2	0.0000	.	2	0.0000	.	2
Straight roadway segments	-1.4841	0.7742		-1.9639	0.6301		-2.9499	0.0007	1
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	2
Number of ramps	-2.6313	0.0156		0.1752	0.8374		-0.0163	0.9285	
Grass median	5.2356	0.0630	2	-6.6797	0.0027	2	0.2440	0.6040	
Grass median with guardrail	5.8386	0.1019	1	-6.4435	0.0223	1	1.3334	0.0260	1
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	-4.1266	0.0004		2.8747	0.0017		-0.5550	0.0043	
Upstream off ramps	-1.6988	0.1161		1.5950	0.0615		0.1330	0.4621	
Downstream on ramps	-2.3962	0.0192		0.8832	0.2715		-0.1874	0.2723	
Downstream off ramps	-4.5296	0.0006		3.5566	0.0006		-0.3184	0.1465	
	R-Squared = 0.123809			R-Squared = 0.098387			R-Squared = 0.135803		

5.4.4.3 Morning/ Early Afternoon Off Peak Hour Comparison

As seen in Table 5-39, the construction activities that impacted the speed were the ITS work and installing loops. It is interesting to note that during this work, there was an increase in speed. The next highest impact was from the pond excavation, digging ditches, and earthwork.

The construction activities that increased the morning/ early afternoon off peak hour occupancy were the stabilization and drainage work.

The construction activities that increased the morning/ early afternoon off peak hour volume were the stabilization, drainage work, pond excavation, digging ditches, and earthwork.

Overall the highest impact to traffic operations from the morning/ early afternoon off peak hour construction activities were the ITS work and installing loops. It is interesting to note that the ITS work and installing loops had an increase in speed of the traffic. This can be attributed to the fact that the daytime ITS work and installing loops were performed off the roadway when the construction was nearly complete and the traffic was flowing close to post construction characteristics. The construction activities that increased the morning/ early afternoon off peak hour occupancy were the stabilization and drainage work. These trends can be attributed to the light flow of traffic during the off peak hours. If a driver slowed down to look at the work taking place, there was not a domino affect of a substantial number of cars that were slowed down as well.

Table 5-48 During construction morning/ early afternoon off peak hour comparison

	Speed			Occupancy			Volume		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	44.4043	<.0001		16.3096	<.0001		18.4235	<.0001	
ITS work and installing loops	6.0358	0.0077	1	-1.4375	0.3718		-0.3361	0.4732	
Stabilization base and drainage work	0.6898	0.5484		2.6139	0.0014	1	1.2308	<.0001	1
Pond excavation, digging ditches, and earthwork	3.1979	0.0145	2	0.1290	0.8897		0.6812	0.0120	2
Pile driving, bridge demolition, and bridge deck work	0.0000	.	3	0.0000	.	2	0.0000	.	3
Paving									
Guardrail and barrier wall									
Straight roadway segments	3.4508	0.3358	1	-1.8956	0.4572		-5.4839	<.0001	1
Curved roadway segments	0.0000	.	2	0.0000	.		0.0000	.	2
Number of ramps	-3.5133	<.0001		-0.2297	0.6660		-0.7740	<.0001	
Grass median	5.3251	0.0035	2	-3.8180	0.0032	2	-0.1123	0.7660	
Grass median with guardrail	-6.0993	0.0701	1	5.0002	0.0368	1	0.6562	0.3466	
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	
Upstream on ramps	-3.8490	<.0001		2.9548	<.0001		-0.1619	0.2765	
Upstream off ramps	-0.5727	0.4279		0.5024	0.3282		0.0100	0.9468	
Downstream on ramps	3.5086	<.0001		-2.1894	<.0001		-0.2570	0.0725	
Downstream off ramps	-2.4830	0.0029		1.9370	0.0011		-0.7606	<.0001	
	R-Squared = 0.179312			R-Squared = 0.088175			R-Squared = 0.103116		

5.4.4.4 Afternoon Off Peak Hour Comparison

It is interesting to note that all of the afternoon off peak hour construction activities were insignificant. See Table 5-40. This can be attributed to the light flow of traffic during the off peak hours.

5.4.4.5 Summary of the Construction Impact Analysis of the Time Segments

The night time work operations had the largest impact from the paving. It had a decrease in speed and had an increase in occupancy. Paving operations involve several pieces of equipment including multiple dump trucks causing a driver distraction. Paving decreased the speed and increased the occupancy. The pile driving, bridge demolition, and bridge deck work increased occupancy.

During the morning peak hours, the paving work had the greatest impact. It had an increase in occupancy and had a decrease in speed. The remainder of the construction activity impacts were insignificant.

The majority of the morning/ early afternoon and the afternoon off peak hour and all of the afternoon off peak hour construction activities were construction activity impacts were insignificant. This can be attributed to the light flow of traffic during the off peak hours.

Table 5-49 During construction afternoon off peak hour comparison

	Speed			Occupancy			Volume		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	37.2244	<.0001		22.0993	<.0001		17.5237	<.0001	
ITS work and installing loops	2.7606	0.3464		1.2584	0.5542		-0.3785	0.7813	
Stabilization base and drainage work	0.9821	0.5091		1.5832	0.1428		0.8361	0.5062	
Pond excavation, digging ditches, and earthwork	0.9613	0.5772		1.2500	0.3181		0.5401	0.6677	
Pile driving, bridge demolition, and bridge deck work	0.0000	.		0.0000	.		-0.4990	0.696	
Paving									
Guardrail and barrier wall									
Straight roadway segments	10.3362	0.0346	1	-5.3306	0.1329	1	-4.4921	<.0001	2
Curved roadway segments	0.0000	.	2	0.0000	.	2	0.0000	.	1
Number of ramps	-2.4599	0.0114		-1.1725	0.0960		-0.3534	0.0743	
Grass median	6.6546	0.0050	2	-6.8699	<.0001	2	0.4453	0.3588	
Grass median with guardrail	10.3491	0.0160	1	-8.9459	0.0042	1	1.1894	0.1776	
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	
Upstream on ramps	-4.3137	<.0001		3.0985	<.0001		-0.4166	0.0327	
Upstream off ramps	0.2123	0.8222		0.1503	0.8265		-0.3178	0.0996	
Downstream on ramps	2.5406	0.0052		-1.0385	0.1151		-0.0440	0.8135	
Downstream off ramps	-1.7098	0.1199		1.1001	0.1680		-1.1553	<.0001	
	R-Squared = 0.170356			R-Squared = 0.060728			R-Squared = 0.097474		

5.4.5 Analysis of Geometric Impacts

5.4.5.1 Night Time Comparison of Geometric Impacts to Speed

As seen in Table 5-41, the parameters during the night time which impacted speed remained about the same before, during, and after construction, however, the magnitude of the effect on speed was different. The straight roadway segments increased speed before and after construction, but not during construction, where it was insignificant. The greatest impact was after construction. The number of ramps was only significant during construction; the impact was that as the number of ramps increased, the speed decreased. The parameters grass median and grass median with guardrail had more of an impact than the median barrier wall. These areas had an increase in speed before, during, and after construction. The grass median had the highest impact after construction was complete and had the least impact during construction. The grass median with guardrail had the highest impact during construction and had the least impact after construction. During construction, the areas with a grass median had more of an impact than areas with a grass median with guardrail. The upstream and downstream on and off ramps had a decrease in speed before, during, and after construction. The highest speed impacts from these parameters were during construction. The least impacts from these parameters were after construction. The highest impact was from the downstream off ramps and the least impacts were at the down steam on ramps.

Table 5-50 Night time comparison of geometric impacts to speed

	During Construction Speed			Before Construction Speed			After Construction Speed		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	63.3027	<.0001		55.0285	<.0001		44.9454	<.0001	
Stabilization base and drainage work	3.2278	0.0181	3						
Pond excavation, digging ditches, and earthwork	5.4910	0.0110	1						
Pile driving, bridge demolition, and bridge deck work	-2.0146	0.1434							
Paving	-4.6690	<.0001	2						
Guardrail and barrier wall	0.0000	.	4						
Straight roadway segments	0.7310	0.8108		5.6179	0.0619	1	7.7819	<.0001	1
Curved roadway segments	0.0000	.		0.0000	0	2	0.0000	.	2
Number of ramps	-3.0563	<.0001		-0.2595	0.5554		-0.1547	0.6341	
Grass median	6.0199	0.0004	2	6.4483	<.0001	1	7.8087	<.0001	1
Grass median with guardrail	7.4593	0.0004	1	5.9207	<.0001	2	5.6159	<.0001	2
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	-4.3966	<.0001		-2.8822	<.0001		-1.1100	0.0012	
Upstream off ramps	-2.2467	0.0007		-1.8111	<.0001		-0.1921	0.5702	
Downstream on ramps	-2.0193	0.0012		-0.8163	0.0609		-1.1893	0.0004	
Downstream off ramps	-5.6710	<.0001		-2.4393	<.0001		-1.5126	<.0001	
	R-Squared = 0.116170			R-Squared = 0.074178			R-Squared = 0.167787		

5.4.5.2 Morning Peak Hours Comparison of Geometric Impacts to Speed

The impact of the straight roadway segments was only significant after construction. It had an increase in speed. The number of ramps was only significant during construction; the impact was that it reduced the speed. Also similar to the night time impacts of geometric characteristics the grass median and the grass median with guardrail parameters had an increase in speed the most before and after construction. The highest impact was before construction. It is interesting to note that before and after construction the grass median had the highest impact and during construction the grass median with guardrail had the highest impact. The upstream on ramps and the downstream off ramps had a decrease in speed before, during, and after construction. The speed impacts of the off and on ramps were the highest during construction and were the lowest after construction. The upstream on ramps had the highest over all impact and the downstream on ramps had the lowest overall impact. See Table 5-42

Table 5-51 Morning peak hours comparison of geometric impacts to speed

	During Construction Speed			Before Construction Speed			After Construction Speed		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	66.2605	<.0001		59.9095	<.0001		44.9349	<.0001	
Stabilization base and drainage work	-0.4430	0.8459							
Pond excavation, digging ditches, and earthwork	4.6790	0.1858							
Pile driving, bridge demolition, and bridge deck work	-1.7950	0.4403							
Paving	-5.2268	0.0019	1						
Guardrail and barrier wall	0.0000	.	2						
Straight roadway segments	-1.4841	0.7742		0.1787	0.9659		9.1542	<.0001	1
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	2
Number of ramps	-2.6313	0.0156		0.0127	0.9845		0.3718	0.3688	
Grass median	5.2356	0.0630	2	7.6491	<.0001	1	6.7914	<.0001	1
Grass median with guardrail	5.8386	0.1019	1	6.2895	0.0003	2	4.1418	0.0002	2
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	-4.1266	0.0004		-2.5963	0.0001		-1.3126	0.0019	
Upstream off ramps	-1.6988	0.1161		-2.0501	0.0006		-0.0796	0.8488	
Downstream on ramps	-2.3962	0.0192		-0.6437	0.295		-0.7372	0.0708	
Downstream off ramps	-4.5296	0.0006		-1.8586	0.0046		-1.0199	0.0226	
	R-Squared = 0.123809			R-Squared = 0.123215			R-Squared = 0.228351		

5.4.5.3 Morning/ Early Afternoon Off Peak Hours Comparison of Geometric Impacts to Speed

The results for morning/ early afternoon off peak hours are different than the night time and morning peak hour results. See Table 5-43. There was no difference between the roadway with straight sections and curved sections before, during, and after construction. The number of ramps had a decrease in speed before, during, and after construction. The impact was the greatest for the number of ramps in the area during construction. The impact was the least for the number of ramps in the area before construction. The grass median with guardrail had the highest impact of the median types. The grass median with guardrail had a decrease in speed and the grass median had an increase in speed. The highest impact from the grass median with guardrail was before construction and the least impact was during construction. The impact of a grass median was insignificant before construction. Unlike the previous two time categories, the off and on ramps had an increase in speed before and after construction. The downstream on ramps had an increase in speed before, during, and after construction. During construction the downstream on ramps had an increase in speed and the upstream on ramps and downstream off ramps had a decrease in speed. The highest impact was at the downstream on ramps and the least impact was at the upstream on ramps. The impact of the upstream off ramps was insignificant.

Table 5-52 Morning/ early afternoon off peak hours comparison of geometric impacts to speed

	During Construction Speed			Before Construction Speed			After Construction Speed		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	44.4043	<.0001		49.3867	<.0001		40.9768	<.0001	
ITS work and installing loops	6.0358	0.0077	1						
Stabilization base and drainage work	0.6898	0.5484							
Pond excavation, digging ditches, and earthwork	3.1979	0.0145	2						
Pile driving, bridge demolition, and bridge deck work	0.0000	.	3						
Straight roadway segments	3.4508	0.3358		-2.7885	0.3573		1.9559	0.4292	
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	
Number of ramps	-3.5133	<.0001		-1.7588	0.0004		-2.3725	<.0001	
Grass median	5.3251	0.0035	2	1.0249	0.4054		2.4598	0.0461	2
Grass median with guardrail	-6.0993	0.0701	1	-9.7186	<.0001	1	-7.2534	0.0016	1
Median barrier wall	0.0000	.	3	0.0000	.	2	0.0000	.	3
Upstream on ramps	-3.8490	<.0001		1.1332	0.0373		2.1596	<.0001	
Upstream off ramps	-0.5727	0.4279		-0.0527	0.9085		-0.4810	0.2792	
Downstream on ramps	3.5086	<.0001		3.7629	<.0001		4.2111	<.0001	
Downstream off ramps	-2.4830	0.0029		2.2088	0.0002		3.9940	<.0001	
	R-Squared = 0.179312			R-Squared = 0.155552			R-Squared = 0.233242		

5.4.5.4 Afternoon Off Peak Hours Comparison of Geometric Impacts to Speed

The results for the afternoon off peak hours are in Table 5-44. There was no difference between the roadway with straight sections and curved sections before construction. The highest impact of increased speed from the straight sections of roadway was during construction and the least impact was after construction. As the number of ramps increased, the speed decreased. The impact was the greatest for the number of ramps during construction. The impact was the least for the number of ramps after construction. The grass median with guardrail had the highest impact for an increase of speed of the median types. The highest impact was during construction and the least impact was before construction. The impact of a grass median was highest after construction and least before construction. The majority of the ramps had an increase in speed. During construction the upstream on ramp had a decrease in speed. The highest impact was at the downstream on ramps and the least impact was at the downstream off ramps. The impact of the upstream off ramps was insignificant before, during, and after construction. The impact of the upstream on ramps was insignificant before and after construction. The impact of the downstream off ramps was insignificant during construction.

Table 5-53 Afternoon off peak hours comparison of geometric impacts to speed

	During Construction Speed			Before Construction Speed			After Construction Speed		
Parameter	Estimate	Pr > |t|	ranking of impact	Estimate	Pr > |t|	ranking of impact	Estimate	Pr > |t|	ranking of impact
Intercept	37.2244	<.0001		46.3351	<.0001		38.5698	<.0001	
ITS work and installing loops	2.7606	0.3464							
Stabilization base and drainage work	0.9821	0.5091							
Pond excavation, digging ditches, and earthwork	0.9613	0.5772							
Pile driving, bridge demolition, and bridge deck work	0.0000	.							
Straight roadway segments	10.3362	0.0346	1	1.4585	0.6367		8.3891	0.0024	1
Curved roadway segments	0.0000	.	2	0.0000	.		0.0000	.	2
Number of ramps	-2.4599	0.0114		-1.6313	0.0023		-1.4421	0.0237	
Grass median	6.6546	0.0050	2	2.6612	0.041	2	6.9569	<.0001	2
Grass median with guardrail	10.3491	0.0160	1	7.6490	0.001	1	8.4615	0.001	1
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	-4.3137	<.0001		0.4099	0.4831		-0.2063	0.7366	
Upstream off ramps	0.2123	0.8222		-0.2281	0.6348		-0.7533	0.136	
Downstream on ramps	2.5406	0.0052		2.9938	<.0001		1.6497	0.0123	
Downstream off ramps	-1.7098	0.1199		2.5778	<.0001		1.2157	0.0822	
	R-Squared = 0.170356			R-Squared = 0.219200			R-Squared = 0.238413		

5.4.5.5 Overall Comparison of Geometric Impacts to Speed

Generally speaking, the parameters had the same ranking of speed impact for the roadway geometric characteristic groups to the speed before, during, and after construction. The straight roadway section had a significant impact at night before and after construction. During the morning peak hours the straight roadway segments were significant after construction. The straight sections of roadway were insignificant before, during, and after construction during the morning/early afternoon off peak hours. In the afternoon, the straight roadway segments were significant during and after construction. The straight sections of roadway had the highest impact during construction during the afternoon off peak hours. The number of ramps decreased the speed before, during, and after construction. The number of ramps was insignificant during the peak morning hours and at night before construction and after construction. The largest impact from the number of ramps was during construction. The grass median had the largest impact during the night time and morning peak time segments before and after construction. The grass median with guardrail had the largest impact during the off peak time segments and during construction during the peak morning hours and at night time. The off and on ramps generally had a decrease in speed during construction and during the peak morning hours and night time. During the off peak hours, the ramps had an increase in speed before and after construction. The upstream off ramps were usually insignificant. During the off peak hours, the downstream on ramps had an increase in speed during construction. The highest ramp impact was during construction.

5.4.5.6 Night Time Comparison of Geometric Impacts to Occupancy

The straight or curved roadway segments were insignificant to the occupancy during and after construction. See Table 5-45. Before construction, the straight roadway segments decreased occupancy. The number of ramps was insignificant before construction. The highest impact from the number of ramps increasing occupancy was during construction. The type of median had a significant difference before and during construction, but not after construction. The grass median with guardrail had the most decrease in occupancy. The impact was the highest during construction. The type of median was insignificant after construction. The off and on ramps had a significant difference before and during construction, but not after construction. The highest impact was during construction. The downstream off ramp had the largest impact.

Table 5-54 Night time comparison of geometric impacts to occupancy

	During Construction Occupancy			Before Construction Occupancy			After Construction Occupancy		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	-2.5539	0.3167		4.9082	0.0024		4.5057	0.0004	
Stabilization base and drainage work	0.4334	0.7054							
Pond excavation, digging ditches, and earthwork	0.9691	0.5926							
Pile driving, bridge demolition, and bridge deck work	3.5823	0.0020	2						
Paving	5.5306	<.0001	1						
Guardrail and barrier wall	0.0000	.	3						
Straight roadway segments	-2.9418	0.2518		-2.7483	0.0769	1	-0.6491	0.5933	
Curved roadway segments	0.0000	.		0.0000	.	2	0.0000	.	
Number of ramps	1.3226	0.0142		-0.1518	0.504		0.3709	0.1015	
Grass median	-6.1375	<.0001	2	-3.0095	<.0001	2	-0.3993	0.4468	
Grass median with guardrail	-6.2671	0.0004	1	-4.5198	<.0001	1	-0.5305	0.3849	
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	
Upstream on ramps	3.4318	<.0001		1.1186	<.0001		-0.2495	0.2945	
Upstream off ramps	3.0515	<.0001		1.3813	<.0001		-0.2883	0.2212	
Downstream on ramps	1.8412	0.0005		0.2555	0.2556		0.3592	0.1227	
Downstream off ramps	5.1314	<.0001		1.5518	<.0001		-0.2267	0.3595	
	R-Squared = 0.113125			R-Squared = 0.108444			R-Squared = 0.022386		

5.4.5.7 Morning Peak Hours Comparison of Geometric Impacts to Occupancy

The straight or curved roadway segments were insignificant to the occupancy before and during construction during the morning peak hours. After construction, the straight roadway segments decreased occupancy. The number of ramps was insignificant before, during, and after construction. The type of median had a significant difference before, during, and after construction. The grass median with guardrail had a decrease in occupancy the most before and during construction. After construction, the type of median increased the occupancy. The impact was the highest during construction and the least after construction. The upstream ramps generally had a significant difference before, during, and after construction. The upstream ramps had an increase in occupancy before and during construction, however, after construction, the upstream ramps had a decrease in occupancy. See Table 5-46.

Table 5-55 Morning peak hours comparison of geometric impacts to occupancy

	During Construction Occupancy			Before Construction Occupancy			After Construction Occupancy		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	2.5500	0.5287		7.5219	0.0001		7.7761	<.0001	
Stabilization base and drainage work	1.9952	0.2671							
Pond excavation, digging ditches, and earthwork	-0.8357	0.7640							
Pile driving, bridge demolition, and bridge deck work	2.3105	0.2079							
Paving	4.8046	0.0003	1						
Guardrail and barrier wall	0.0000	.	2						
Straight roadway segments	-1.9639	0.6301		-2.1290	0.2525		-3.9342	<.0001	1
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	2
Number of ramps	0.1752	0.8374		-0.2047	0.4805		0.2089	0.1607	
Grass median	-6.6797	0.0027	2	-1.1357	0.0887	2	0.6958	0.042	2
Grass median with guardrail	-6.4435	0.0223	1	-2.2978	0.0031	1	1.2547	0.0014	1
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	2.8747	0.0017		-0.2463	0.4049		-0.4792	0.0016	
Upstream off ramps	1.5950	0.0615		1.1371	<.0001		-0.3787	0.0121	
Downstream on ramps	0.8832	0.2715		-0.3333	0.2231		-0.0123	0.9329	
Downstream off ramps	3.5566	0.0006		0.0148	0.9593		-0.2245	0.1617	
	R-Squared = 0.098387			R-Squared = 0.116177			R-Squared = 0.136017		

5.4.5.8 Morning/ Early Off Peak Afternoon Hours Comparison of Geometric Impacts to Occupancy

The straight or curved roadway segments were insignificant to the occupancy before and during construction during the morning/ early afternoon off peak hours. After construction, the straight roadway segments decreased occupancy. The number of ramps was insignificant before and during construction. After construction, the number of ramps increased occupancy. The type of median had a significant difference before, during, and after construction. The grass median with guardrail increased the occupancy the most. The grass median had a decrease in occupancy before and during construction, but had an increase in occupancy after construction. The upstream on ramps and downstream off and on ramps had a significant difference before, during, and after construction. Before and after construction the upstream on ramps and downstream on and off ramps had a decrease in occupancy. During construction the upstream on ramps and downstream off ramps had an increase in occupancy. See Table 5-47.

Table 5-56 Morning / early afternoon off peak hours comparison of geometric impacts to occupancy

	During Construction Occupancy			Before Construction Occupancy			After Construction Occupancy		
Parameter	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	16.3096	<.0001		14.1208	<.0001		20.7162	<.0001	
ITS work and installing loops	-1.4375	0.3718							
Stabilization base and drainage work	2.6139	0.0014	1						
Pond excavation, digging ditches, and earthwork	0.1290	0.8897							
Pile driving, bridge demolition, and bridge deck work	0.0000	.	2						
Straight roadway segments	-1.8956	0.4572		1.1032	0.5174		-3.4638	0.0529	1
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	2
Number of ramps	-0.2297	0.6660		0.1247	0.6563		2.2798	<.0001	
Grass median	-3.8180	0.0032	2	-2.1106	0.0024	2	3.4079	0.0001	2
Grass median with guardrail	5.0002	0.0368	1	8.8257	<.0001	1	7.0521	<.0001	1
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	2.9548	<.0001		-1.1798	0.0001		-4.0573	<.0001	
Upstream off ramps	0.5024	0.3282		-0.3321	0.1976		-0.2581	0.4219	
Downstream on ramps	-2.1894	<.0001		-0.9340	0.001		-2.9863	<.0001	
Downstream off ramps	1.9370	0.0011		-0.7742	0.0214		-4.6638	<.0001	
	R-Squared = 0.088175			R-Squared = 0.153161			R-Squared = 0.229043		

5.4.5.9 Afternoon Off Peak Hours Comparison of Geometric Impacts to Occupancy

The straight or curved roadway segments were insignificant to the occupancy before and during construction in the early afternoon off peak hours. After construction, the straight roadway segments decreased occupancy. The number of ramps was insignificant before construction. During construction, as the number of ramps increased, the occupancy decreased and after construction, the number of ramps had an increase in occupancy. The type of median had a significant difference before, during, and after construction. The type of median had a decrease in occupancy before and during construction, however, areas with a grass median had an increase in occupancy after construction. The upstream on ramps had a significant difference before, during, and after construction. Before and after construction the downstream off ramps had a decrease in occupancy. The impact of the upstream off ramps was insignificant. See Table 5-48.

5.4.5.10 Overall Comparison of Geometric Impacts to Occupancy

Generally speaking, the parameters had the same ranking of occupancy impact for the roadway geometric characteristic groups to the occupancy before, during, and after construction. The straight roadway section had a significant impact before construction at night time and after construction during the morning peak hours, after construction during the morning/ early afternoon off peak, and after construction during the afternoon off peak hours. The highest impact was during the afternoon off peak hours. The number of ramps increased occupancy after construction for the majority of the time segments and was insignificant before construction for all the time categories analyzed. The number of ramps had a decrease in occupancy before and during construction, however, had an increase in occupancy after construction. Generally speaking before and during construction the type of median had a decrease in occupancy, however, after construction; the type of median had an increase in occupancy. The grass median with guardrail had the largest impact for the type of median. The off and on ramps before and during construction had an increase in occupancy at night and during the peak morning hours. During the off peak hours, before construction the occupancy had a decrease at the off and on ramps. Generally speaking during and after construction, the off and on ramps showed decreased occupancy. The largest impact was during construction at night time.

Table 5-57 Afternoon off peak hours comparison of geometric impacts to occupancy

	During Construction Occupancy			Before Construction Occupancy			After Construction Occupancy		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	22.0993	<.0001		14.3630	<.0001		22.5091	<.0001	
ITS work and installing loops	1.2584	0.5542							
Stabilization base and drainage work	1.5832	0.1428							
Pond excavation, digging ditches, and earthwork	1.2500	0.3181							
Pile driving, bridge demolition, and bridge deck work	0.0000	.							
Straight roadway segments	-5.3306	0.1329		0.3823	0.8035		-9.0969	<.0001	1
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	2
Number of ramps	-1.1725	0.0960		-0.0522	0.844		2.0368	<.0001	
Grass median	-6.8699	<.0001	2	-3.2877	<.0001	1	2.3247	0.0221	1
Grass median with guardrail	-8.9459	0.0042	1	-3.0240	0.0089	2	1.9260	0.3016	
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	2
Upstream on ramps	3.0985	<.0001		-0.7674	0.0084		-2.7848	<.0001	
Upstream off ramps	0.1503	0.8265		-0.1651	0.4897		0.0542	0.8832	
Downstream on ramps	-1.0385	0.1151		-0.3651	0.1791		-1.4228	0.0031	
Downstream off ramps	1.1001	0.1680		-0.9043	0.0048		-3.4931	<.0001	
	R-Squared = 0.060728			R-Squared = 0.184201			R-Squared = 0.217476		

5.4.5.11 Night Time Comparison of Geometric Impacts to Volume

There were no significant impacts between the curved sections of roadway and the straight sections of the roadway. The number of ramps in the area was significant after construction; it increased the volume. The type of median was significant before construction. The grass median with guardrail had the most decrease in volume. The upstream on ramp was significant after construction and had a decrease in volume. The upstream off ramp was significant before and during construction and had an increase in volume. The downstream on ramp was only significant before construction and had an increase in volume. The downstream off ramp had an increase in speed before construction and decreased the speed after construction, but was insignificant during construction. See Table 5-49.

5.4.5.12 Morning Peak Hour Comparison of Geometric Impacts to Volume

There was a significant difference during construction from the impacts of straight versus a curved section of roadway during construction. Straight sections of roadway decreased the volume. The number of ramps was insignificant before, during, and after construction. The type of median was significant during and after construction. The median with guardrail had an increase in volume the most. The upstream on ramps and the downstream off ramps had the most significant impacts of the off and on ramps. The ramps had a decrease in volume. The highest impact was before construction. Table 5-50.

Table 5-58 Night time comparison of geometric impacts to volume

	During Construction Volume			Before Construction Volume			After Construction Volume		
Parameter	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	4.2445	<.0001		4.5796	<.0001		3.8652	<.0001	
Stabilization base and drainage work	1.0049	0.0006	1						
Pond excavation, digging ditches, and earthwork	0.2851	0.5375							
Pile driving, bridge demolition, and bridge deck work	0.3107	0.2927							
Paving	0.3688	0.0971	2						
Guardrail and barrier wall	0.0000	.	3						
Straight roadway segments	-0.5588	0.3937		0.3827	0.6955		0.4610	0.4744	
Curved roadway segments	0.0000	.		0.0000	.		0.0000	.	
Number of ramps	0.1303	0.3435		-0.1914	0.1815		0.4432	0.0002	
Grass median	-0.0487	0.8929		-1.5150	<.0001	2	0.3477	0.2116	
Grass median with guardrail	-0.4056	0.3695		-2.7670	<.0001	1	-0.2312	0.4752	
Median barrier wall	0.0000	.		0.0000	.	3	0.0000	.	
Upstream on ramps	-0.1245	0.4092		-0.0731	0.626		-0.5337	<.0001	
Upstream off ramps	0.4070	0.0043		0.5638	<.0001		0.0515	0.6799	
Downstream on ramps	0.2134	0.1104		0.3065	0.0305		0.0434	0.725	
Downstream off ramps	0.1153	0.4939		0.3378	0.0201		-0.2405	0.0669	
	R-Squared = 0.042103			R-Squared = 0.090071			R-Squared = 0.050345		

Table 5-59 Peak morning hours comparison of geometric impacts to volume

	During Construction Volume			Before Construction Volume			After Construction Volume		
Parameter	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	8.8450	<.0001		11.4691	<.0001		6.4700	<.0001	
Stabilization base and drainage work	0.9645	0.0120	1						
Pond excavation, digging ditches, and earthwork	-0.8845	0.1355							
Pile driving, bridge demolition, and bridge deck work	-0.0812	0.8348							
Paving	0.2757	0.3239							
Guardrail and barrier wall	0.0000	.	2						
Straight roadway segments	-2.9499	0.0007	1	-2.5851	0.1439		-0.9187	0.3011	
Curved roadway segments	0.0000	.	2	0.0000	.		0.0000	.	
Number of ramps	-0.0163	0.9285		-0.3702	0.1796		0.2353	0.1497	
Grass median	0.2440	0.6040		-0.6075	0.3368		0.8733	0.0201	2
Grass median with guardrail	1.3334	0.0260	1	-0.8051	0.2718		1.2749	0.0031	1
Median barrier wall	0.0000	.	2	0.0000	.		0.0000	.	3
Upstream on ramps	-0.5550	0.0043		-1.0860	0.0001		-0.8749	<.0001	
Upstream off ramps	0.1330	0.4621		0.0450	0.8568		-0.3112	0.0596	
Downstream off ramps	-0.1874	0.2723		-0.2387	0.3579		-0.0953	0.5531	
Downstream off ramps	-0.3184	0.1465		-0.5112	0.0641		-0.5015	0.0046	
	R-Squared = 0.135803			R-Squared = 0.124704			R-Squared = 0.116552		

5.4.5.13 Morning/Early Afternoon Off Peak Hour Comparison of Geometric Impacts to Volume

The impact from a curved section of roadway versus a straight section was significant before, during, and after construction. The highest impact was before construction, where the volume was decreased and the least impact was after construction. The number of ramps was significant before, during, and after construction. Before and during construction, as the number of ramps increased, the volume decreased. After construction, as the number of ramps increased, the volume increased. The type of median was significant during and after construction. Before construction the type of median had a decrease in volume, after construction, the type of median had an increase in volume. The off and on ramps had a decrease in volume. The highest impact of decrease in volume was after construction. The least impact was during construction. The upstream off ramps were insignificant before and during construction. See Table 5-51.

5.4.5.14 Afternoon Off Peak Hour Comparison of Geometric Impacts to Volume

The impact from a curved section of roadway versus a straight section was significant during construction. where the volume was decreased. The number of ramps was significant during and after construction. Before and during construction, as the number of ramps increased, the volume decreased. After construction, as the number of ramps increased, the volume increased. The type of median was significant before and after construction. Before construction the type of median had a decrease in volume, after construction, the type of median had an increase in volume. The off and on ramps decreased the volume. The highest impact of decrease in volume was after construction. The least impact was during construction. The upstream off ramps were insignificant before and during construction. See Table 5-52.

Table 5-60 Morning/ early afternoon off peak morning hours comparison of geometric impacts to volume

	During Construction Volume			Before Construction Volume			After Construction Volume		
Parameter	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	18.4235	<.0001		18.9053	<.0001		13.5811	<.0001	
ITS work and installing loops	-0.3361	0.4732							
Stabilization base and drainage work	1.2308	<.0001	1						
Pond excavation, digging ditches, and earthwork	0.6812	0.0120	2						
Pile driving, bridge demolition, and bridge deck work	0.0000	.	3						
Straight roadway segments	-5.4839	<.0001	1	-1.5768	0.0034	1	-0.9122	0.0361	1
Curved roadway segments	0.0000	.	2	0.0000	.	2	0.0000	.	2
Number of ramps	-0.7740	<.0001		-0.3623	<.0001		1.1262	<.0001	
Grass median	-0.1123	0.7660		-1.6428	<.0001	1	1.6444	<.0001	2
Grass median with guardrail	0.6562	0.3466		-0.6164	0.1042	2	6.1532	<.0001	1
Median barrier wall	0.0000	.		0.0000	.	3	0.0000	.	3
Upstream on ramps	-0.1619	0.2765		-1.3436	<.0001		-1.1369	<.0001	
Upstream off ramps	0.0100	0.9468		-0.1067	0.1888		-0.6017	<.0001	
Downstream on ramps	-0.2570	0.0725		-0.8127	<.0001		-0.5178	<.0001	
Downstream off ramps	-0.7606	<.0001		-0.8771	<.0001		-1.2760	<.0001	
	R-Squared = 0.103116			R-Squared = 0.412600			R-Squared = 0.372860		

Table 5-61 Afternoon off peak morning hours comparison of geometric impacts to volume

	During Construction Volume			Before Construction Volume			After Construction Volume		
Parameter	**Estimate**	**Pr > |t|**	**Ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**	**Estimate**	**Pr > |t|**	**ranking of impact**
Intercept	22.0993	<.0001		18.7135	<.0001		13.5215	<.0001	
ITS work and installing loops	1.2584	0.5542							
Stabilization base and drainage work	1.5832	0.1428							
Pond excavation, digging ditches, and earthwork	1.2500	0.3181							
Pile driving, bridge demolition, and bridge deck work	0.0000	.							
Straight roadway segments	-5.3306	0.1329		-1.8145	0.0017	1	-0.4093	0.4508	
Curved roadway segments	0.0000	.		0.0000	.	2	0.0000	.	
Number of ramps	-1.1725	0.0960		-0.0023	0.9814		1.0070	<.0001	
Grass median	-6.8699	<.0001	2	-1.2612	<.0001	1	1.4341	<.0001	2
Grass median with guardrail	-8.9459	0.0042	1	-0.7422	0.0872	2	5.1100	<.0001	1
Median barrier wall	0.0000	.	3	0.0000	.	3	0.0000	.	3
Upstream on ramps	3.0985	<.0001		-1.4396	<.0001		-1.0435	<.0001	
Upstream off ramps	0.1503	0.8265		-0.1271	0.1573		-0.7216	<.0001	
Downstream on ramps	-1.0385	0.1151		-0.4887	<.0001		-0.5060	<.0001	
Downstream off ramps	1.1001	0.1680		-1.2631	<.0001		-1.4474	<.0001	
	R-Squared = 0.097474			R-Squared = 0.512994			R-Squared = 0.447308		

5.4.5.15 Overall Comparison of Geometric Impacts to Volume

The overall impact to the volume from a straight section of roadway was significant during the off peak morning/ early afternoon hours. The impact was a decrease in volume and the greatest impact was during construction. The number of ramps was also typically significant during the off peak hours. The impact was that the volume decreased as the number of ramps increased before and during construction. The type of median was not significant during construction during any of the time segments analyzed, during the night, and for the most part during the peak morning hours. During the off peak hours, the type of median had a tendency to have an impact of decreasing the volume before and during construction. After construction, the type of median had an impact of increasing the volume. Generally speaking the off and on ramps had a decrease in volume during the morning peak hours and the off peak hours. At night the impacts of the off and on ramps tended to have an increase in volume. The impact was the greatest before construction during the morning/ early afternoon off peak hours.

5.5 Summary

The purpose of this chapter was to quantify the impact of the construction activities and the geometric conditions of the roadway on speed, volume, and occupancy utilizing the linear models with categorical and continuous independent variables. The data cross referenced the roadway geometric conditions and models were developed. The linear models are a sub-class of General(ized) Linear Models (GLM) of which Linear Regression and Analysis of Covariance (ANCOVA) are special cases. Linear Regression and ANCOVA were used to understand the presence of geometrics before, during, and after construction activities. Models for speed, occupancy, and volume were generated for before, during, and after construction. The models were then compared for similarities and differences for impacts from construction activities and determined how the presence of construction and roadway improvements changed the impacts from the geometric roadway conditions.

Similar work was grouped together for the LRM analysis. For example, work that had similar types of equipment that took place at similar times of the day or was in the same general category The groups formed were:

1. ITS work and installing loops
2. Stabilization base and drainage work
3. Pond excavation, digging ditches, and earthwork
4. Pile driving, bridge demolition, and bridge deck work
5. Paving
6. Guardrail and barrier wall.

It is interesting to note that the R-Squared values were higher for before and after construction. This indicates that the models for before and after construction are more accurate than the during construction models. This shows that random errors during construction increased.

The timings of the work were divided into four categories representing the time of day for the purpose of the LRM analysis:

10:30 pm to 5:00 am – Representing the night traffic.

7:00 am to 8:30 am – Representing the morning peak traffic.

8:30 am to 1:30 pm – Representing the morning/ early afternoon off peak traffic.

1:30 pm to 3:00 pm – Representing the afternoon off peak traffic.

There were 6 groups formed and the timings of the work were divided into 4 categories.

The impact of construction on speed, occupancy, and volume during the four time categories were next discussed.

The next step was to analyze the geometric impacts by looking at the before, during, and after estimates for the parameters of the four time categories analyzed.

CHAPTER 6 CONCLUSION

6.1 General

In this thesis, the impact of various construction activities and the roadway geometric characteristics to speed, occupancy, and volume were evaluated. It is important to know which construction activities are most likely to cause a delay so that agencies contracting for construction projects can be aware of the variables that cause the greatest delays to the traveling public, especially for highly congested areas. The methods chosen to analyze the data were matched case logistic regression and general linear model. This chapter summarizes the conclusions developed and the future scope is discussed.

6.2 Previous Research

Many studies have been conducted showing that construction has a significant impact on congestion. FHWA produced a report that states work zones are responsible for 24% of non–recurring congestion (FHWA, 2003). Research was conducted on impacts of phasing of work zones and general construction, driver characteristics in work zones and modeling using programs such as WATSIM, CORSIM, PARAMICS, etc to predict delays. No research was found showing which types of construction work and the various roadway geometrics impact the speed, volume, and occupancy.

6.3 Data Collection and Analysis

The data collection for this was extensive, as it required reviewing three construction projects and taking notes of the various days, types of activities performed, location, etc. The construction projects analyzed were three Design–Build projects on Interstate 4 in Orlando, Florida. The construction work began in August 2001 and was completed in July 2004. These projects are typical to any interstate roadway widening projects. The data were obtained from FDOT. The locations were cross referenced to the loop detectors in the roadway. The data for the volume, speed, and occupancy were collected for the days during construction, year preceding construction, and the year after construction. The roadway characteristics of median type, roadway radius, etc, were also collected.

6.4 Matched Case Logistic Regression Conclusions

Logistic regression was the analysis method chosen for this research for several reasons. Since there was data that can be matched and dependent variables that can be controlled, it was very useful. Logistic regression analysis under the within stratum matched sampling framework was conducted as an exploratory analysis to see if there was a difference on the traffic impact with and without construction. This was done by matching the variables to ensure that there was no other difference impacting the traffic operations. Logistic regression proved there was a difference with and without the presence of construction.

The simple model results demonstrated that speed was reduced, occupancy was increased, and volume decreased during construction. After construction, the speed increased, the occupancy decreased and volume increased.

6.5 Linear Regression and Analysis of Covariance

The purpose of the Linear Regression and Analysis of Covariance was to quantify the impact of the construction activities and the geometric conditions of Interstate 4 on speed, volume, and occupancy utilizing the linear models with categorical and continuous independent variables. The data cross referenced the roadway geometric conditions and models were developed. The linear models are a sub-class of General(ized) Linear Models (GLM) of which Linear Regression and Analysis of Covariance (ANCOVA) are special cases. Linear Regression and ANCOVA were used to understand the presence of geometrics before, during, and after construction activities. Models for speed, occupancy, and volume were generated for before, during, and after construction. The models were then compared for similarities and differences for impacts from construction activities and determined how the presence of construction and roadway improvements changed the impacts from the geometric roadway conditions.

First, each of the individual models for speed, occupancy, and volume for before, during, and after construction were discussed.

The impact of construction on speed, occupancy, and volume during the four time categories were discussed next. The night time work operations had the largest impact from the paving. It had a decrease in speed and had an increase in occupancy. Paving operations involve several pieces of equipment including multiple dump trucks causing a driver distraction. Paving decreased the speed and increased the occupancy. The pile driving, bridge demolition, and bridge deck work had an increase in occupancy.

During the morning peak hours, the paving work had the greatest impact. It had an increase in occupancy and had a decrease in speed. The remainder of the construction activity impacts were insignificant.

The majority of the morning/ early afternoon and the afternoon off peak hour and all of the afternoon off peak hour construction activities were insignificant. This can be attributed to the light flow of traffic during the off peak hours.

The last step was to analyze the geometric impacts by looking at the before, during, and after estimates of the parameters for the various time segments analyzed.

Generally speaking, the parameters had the same ranking of speed impact for the roadway geometric characteristic groups to the speed before, during, and after construction. The straight roadway section had a significant impact increasing the speed at night before and after construction. During the morning peak hours the straight roadway segments were significant after construction. The straight sections of roadway were insignificant before, during, and after construction during the morning/early afternoon off peak hours. In the afternoon, the straight roadway segments were significant during and after construction. The straight sections of roadway had the highest impact during construction during the afternoon off peak hours. The number of ramps decreased the speed before, during, and after construction. The number of ramps was insignificant during the peak morning hours and at night before construction and after construction. The largest impact from the number of ramps was during construction. The grass median had the largest impact during the night time and morning peak time segments before and after construction. The grass median with guardrail had the largest impact during the off peak time segments and during construction during the peak morning hours and at night time. The off and on ramps generally had a decrease in speed during construction and during the peak morning hours and night time. During the off peak hours, the ramps had an increase in speed before and after construction. The upstream off ramps were usually insignificant.   During the off peak hours, the downstream on ramps had an increase in speed during construction. The highest ramp impact was during construction.

Generally speaking, the parameters had the same ranking of occupancy impact for the roadway geometric characteristic groups to the occupancy before, during, and after construction. The straight roadway section had a significant impact decreasing occupancy before construction at night time and after construction during the morning peak hours, after construction during the morning/ early afternoon off peak, and after construction during the afternoon off peak hours. The highest impact was during the afternoon off peak hours. The number of ramps increased occupancy after construction for the majority of the time segments and was insignificant before construction for all the time categories analyzed. The number of ramps had a decrease in occupancy before and during construction, however, had an increase in occupancy after construction. Generally speaking before and during construction the type of median had a decrease in occupancy, however, after construction; the type of median had an increase in occupancy. The grass median with guardrail had the largest impact for the type of median. The off and on ramps before and during construction had an increase in occupancy at night and during the peak morning hours. During the off peak hours, before construction the occupancy had a decrease at the off and on ramps. Generally speaking during and after construction, the off and on ramps showed a decrease in occupancy. The largest impact was during construction at night time.

The overall impact to the volume from a straight section of roadway was significant during the off peak morning/ early afternoon hours. The impact was a decrease in volume and the greatest impact was during construction. The number of ramps was also typically significant during the off peak hours. The impact was that the volume decreased as the number of ramps increased before and during construction. The type of median was not significant during construction during during the night, and for the most part during the peak morning hours. During the off peak hours, the type of median had a tendency to have an impact of decreasing the volume before and during construction. After construction, the type of median had an impact of increasing the volume. Generally speaking the off and on ramps had a decrease in volume during the morning peak hours and the off peak hours. At night the impacts of the off and on ramps tended to have an increase in volume. The impact was the greatest before construction during the morning/ early afternoon off peak hours.

6.6 Future Scope

In conclusion, the results of this research demonstrate that certain construction activities have larger impacts to traffic operations than others. This thesis also demonstrated that some impacts of the roadway geometrics are different before and after construction. This information can be used by agencies that have funding for construction projects. As times are changing, agencies are becoming more and more accountable to the public for impacts from construction projects. Agencies writing construction contracts should prohibit paving during the most highly congested times. For example, in Orlando, Florida on Interstate 4, agencies should prohibit night paving during the peak holiday seasons (such as Thanksgiving, spring breaks, Christmas, etc.) around the tourist attractions during closing times, during the peak morning hours, and during the closing times of high attendance activities, such as Halloween Horror Nights at Universal Studios when high attendance is anticipated at the theme parks. Roadway geometrics also impact the traffic operations differently, before, during, and after construction and differently during various times of the day. The information of improved roadway geometrics and faster traffic flow can be used at open houses for upcoming projects where there are many people opposed to construction projects to show how the roadway construction projects actually increase traffic flow, helping everyone to get to their destinations much faster and would be proof of why the projects are of value to the traveling public. As more construction projects take place where loop data is available before, during, and after construction, the impacts of more specific types of work such as placing rebar on bridge substructures and superstructures, installing light pole bases, placing concrete for drilled shafts, etc. can also be evaluated for traffic impacts. The impact of the traffic delays in the congested areas, such as the tourist areas on Interstate 4 during the peak traffic times could be quantified to calculate delay costs to the roadway users.

APPENDIX A DATA COLLECTION

Table A-1 Sample of Data Collected from Daily Reports of Construction

Case Number	Date	Date	Time	Station	Direction	Time–Range	Station–Range	Station In Dailies	Type Of Work	Type Number
1	6/2/2002	Sunday	23:30	17	E	22:00–24:00	17	758–792	paving	3
2	6/3/2002	Monday	1:30	17	E	0:00–2:00	17	758–792	paving	3
3	6/3/2002	Monday	4:00	17	E	2:00–4:00	17	758–792	paving	3
4	6/3/2002	Monday	6:00	17	E	4:00–6:00	17	758–792	paving	3
5	6/5/2002	Wednesday	23:30	18	E	22:00–24:00	18	764–808	paving	3
6	6/6/2002	Thursday	1:30	18	E	0:00–2:00	18	764–808	paving	3
7	6/6/2002	Thursday	4:00	18	E	2:00–4:00	18	764–808	paving	3
8	6/6/2002	Thursday	6:00	18	E	4:00–6:00	18	764–808	paving	3
9	6/6/2002	Thursday	23:30	19	E	22:00–24:00	19	808–835	paving	3
10	6/7/2002	Friday	1:30	19	E	0:00–2:00	19	808–835	paving	3
11	6/7/2002	Friday	4:00	19	E	2:00–4:00	19	808–835	paving	3
12	6/7/2002	Friday	6:00	19	E	4:00–6:00	19	808–835	paving	3
13	6/7/2002	Friday	23:30	20	E	22:00–24:00	20	835–852	paving	3
14	6/8/2002	Saturday	1:30	20	E	0:00–2:00	20	835–852	paving	3
15	6/8/2002	Saturday	4:00	20	E	2:00–4:00	20	835–852	paving	3
16	6/8/2002	Saturday	6:00	20	E	4:00–6:00	20	835–852	paving	3
17	6/11/2002	Tuesday	23:30	18	E	22:00–24:00	17–19	744–836	paving	3
18	6/12/2002	Wednesday	1:30	18	E	0:00–2:00	17–19	744–836	paving	3
19	6/12/2002	Wednesday	4:00	18	E	2:00–4:00	17–19	744–836	paving	3
20	6/12/2002	Wednesday	6:00	18	E	4:00–6:00	17–19	744–836	paving	3
21	6/11/2002	Tuesday	23:30	18	E	22:00–24:00	17–19	752–836	paving	3
22	6/12/2002	Wednesday	1:30	18	E	0:00–2:00	17–19	752–836	paving	3
23	6/12/2002	Wednesday	4:00	18	E	2:00–4:00	17–19	752–836	paving	3
24	6/12/2002	Wednesday	6:00	18	E	4:00–6:00	17–19	752–836	paving	3
25	6/12/2002	Wednesday	23:30	20	E	22:00–24:00	20	836–852	paving	3
26	6/13/2002	Thursday	1:30	20	E	0:00–2:00	20	836–852	paving	3
27	6/13/2002	Thursday	4:00	20	E	2:00–4:00	20	836–852	paving	3
28	6/13/2002	Thursday	6:00	20	E	4:00–6:00	20	836–852	paving	3
29	6/13/2002	Thursday	23:30	17	E	22:00–24:00	17	758–768	paving	3
30	6/14/2002	Friday	1:30	17	E	0:00–2:00	17	758–768	paving	3

Table A–2. Roadway Characteristics Inventory.

Loop	Direction	Radius	Lanes	Median Type	Median Width	Type Of Pavment	Number Of Number of ramps At Loop
2	E	17189	3	Grass	372	HIGH ASPHALT	0
3	E	17189	3	Grass	372	HIGH ASPHALT	1
4	E	0	2	Grass	372	HIGH ASPHALT	1
5	E	0	2	Grass	44	HIGH ASPHALT	2
6	E	85944	2	Grass	44	HIGH ASPHALT	2
7	E	0	3	Grass	64	HIGH ASPHALT	0
8	E	0	3	Grass	64	HIGH ASPHALT	0
9	E	0	4	Grass	64	HIGH ASPHALT	1
10	E	0	3	Grass	64	HIGH ASPHALT	2
11	E	0	3	Grass	64	HIGH ASPHALT	1
12	E	0	3	Grass	64	HIGH ASPHALT	0
13	E	0	3	Grass	64	HIGH ASPHALT	0
14	E	0	3	Grass	64	HIGH ASPHALT	1
15	E	0	3	Grass	64	HIGH ASPHALT	1
16	E	0	4	Grass	64	HIGH ASPHALT	0
17	E	0	3	Grass	64	HIGH ASPHALT	1
18	E	0	3	Grass	64	HIGH ASPHALT	0
19	E	0	3	Grass	64	HIGH ASPHALT	1
20	E	0	3	Grass	64	HIGH ASPHALT	0
21	E	2865	4	Grass	165	HIGH ASPHALT	1
22	E	0	3	Grass	165	HIGH ASPHALT	1
23	E	2865	4	Grass	165	HIGH ASPHALT	2
24	E	2865	4	Grass	165	HIGH ASPHALT	1
25	E	0	3	Grass	64	HIGH ASPHALT	1
26	E	0	4	Grass	64	HIGH ASPHALT	1
27	E	7639	4	Grass	64	HIGH ASPHALT	2
28	E	0	4	Grass	64	HIGH ASPHALT	0
29	E	0	4	Grass	64	HIGH ASPHALT	0
30	E	2865	3	Grass	64	HIGH ASPHALT	1
31	E	0	3	Grass	64	HIGH ASPHALT	1

Loop	Direction	Radius	Lanes	Median Type	Median Width	Type Of Pavment	Number Of Number of ramps At Loop
32	E	0	4	Grass	140	HIGH ASPHALT	0
33	E	0	3	Grass	140	CONCRETE	3
34	E	0	3	PTD. with barrier	42	CONCRETE	2
35	E	0	3	PTD. with barrier	42	CONCRETE	2
36	E	0	4	PTD. with barrier	42	CONCRETE	2
37	E	1910	3	PTD. with barrier	32	CONCRETE	1
38	E	2292	3	PTD. with barrier	140	CONCRETE	3
40	E	0	3	PTD. with barrier	28	CONCRETE	2
41	E	0	3	PTD. with barrier	28	CONCRETE	1
42	E	0	3	PTD. with barrier	28	CONCRETE	2
43	E	2292	3	PTD. with barrier	40	HIGH ASPHALT	1
44	E	3820	3	PTD. with barrier	40	CONCRETE	1
45	E	0	3	PTD. with barrier	16	CONCRETE	1
46	E	0	3	PTD. with barrier	16	CONCRETE	1
47	E	0	3	PTD. with barrier	16	CONCRETE	1
48	E	0	3	PTD. with barrier	16	CONCRETE	1
49	E	0	3	PTD. with barrier	16	CONCRETE	1
50	E	0	3	Grass	40	CONCRETE	0
51	E	0	4	Grass	40	CONCRETE	0
52	E	0	4	Grass	40	CONCRETE	2
53	E	5730	3	Grass	40	CONCRETE	0
54	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1
55	E	17189	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
56	E	0	4	LAWN & GU.RAIL	40	HIGH ASPHALT	1
57	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1
58	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
59	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
60	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1
61	E	0	3	Grass	128	HIGH ASPHALT	1
62	E	5730	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
63	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
64	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
65	E	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1

Loop	Direction	Radius	Lanes	Median Type	Median Width	Type Of Pavment	Number Of Number of ramps At Loop
66	E	0	3	Grass	64	HIGH ASPHALT	1
67	E	0	3	Grass	64	HIGH ASPHALT	0
68	E	0	3	Grass	64	HIGH ASPHALT	0
69	E	0	2	Grass	64	HIGH ASPHALT	1
70	E	0	2	Grass	64	HIGH ASPHALT	1
71	E	0	2	Grass	64	HIGH ASPHALT	1
2	W	17189	3	Grass	372	HIGH ASPHALT	0
3	W	17189	3	Grass	372	HIGH ASPHALT	1
4	W	0	2	Grass	372	HIGH ASPHALT	2
5	W	0	2	Grass	44	HIGH ASPHALT	1
6	W	85944	2	Grass	44	HIGH ASPHALT	1
7	W	0	3	Grass	64	HIGH ASPHALT	2
8	W	0	3	Grass	64	HIGH ASPHALT	0
9	W	0	3	Grass	64	HIGH ASPHALT	1
10	W	0	3	Grass	64	HIGH ASPHALT	1
11	W	0	3	Grass	64	HIGH ASPHALT	0
12	W	0	3	Grass	64	HIGH ASPHALT	1
13	W	0	3	Grass	64	HIGH ASPHALT	0
14	W	0	3	Grass	64	HIGH ASPHALT	1
15	W	0	3	Grass	64	HIGH ASPHALT	0
16	W	0	3	Grass	64	HIGH ASPHALT	1
17	W	0	3	Grass	64	HIGH ASPHALT	1
18	W	0	3	Grass	64	HIGH ASPHALT	0
19	W	0	4	Grass	64	HIGH ASPHALT	1
20	W	0	4	Grass	64	HIGH ASPHALT	2
21	W	2865	3	Grass	165	HIGH ASPHALT	1
22	W	0	3	Grass	165	HIGH ASPHALT	0
23	W	2865	3	Grass	165	HIGH ASPHALT	1
24	W	2865	3	Grass	165	HIGH ASPHALT	1
25	W	0	3	Grass	64	HIGH ASPHALT	1
26	W	0	4	Grass	64	HIGH ASPHALT	2
27	W	7639	4	Grass	64	HIGH ASPHALT	1
28	W	0	4	Grass	64	HIGH ASPHALT	0

Loop	Direction	Radius	Lanes	Median Type	Median Width	Type Of Pavment	Number Of Number of ramps At Loop
29	W	0	4	Grass	64	HIGH ASPHALT	0
30	W	2865	3	Grass	64	HIGH ASPHALT	1
31	W	0	3	Grass	64	HIGH ASPHALT	1
32	W	0	3	Grass	140	HIGH ASPHALT	0
33	W	0	4	Grass	140	CONCRETE	2
34	W	0	3	PTD. with barrier	42	CONCRETE	2
35	W	0	3	PTD. with barrier	42	CONCRETE	2
36	W	0	4	PTD. with barrier	42	CONCRETE	2
37	W	1910	3	PTD. with barrier	32	CONCRETE	2
38	W	2292	4	PTD. with barrier	140	CONCRETE	3
40	W	0	4	PTD. with barrier	28	CONCRETE	1
41	W	0	4	PTD. with barrier	28	CONCRETE	2
42	W	0	4	PTD. with barrier	28	CONCRETE	1
43	W	2292	3	PTD. with barrier	40	HIGH ASPHALT	1
44	W	3820	3	PTD. with barrier	40	CONCRETE	1
45	W	0	3	PTD. with barrier	16	CONCRETE	1
46	W	0	3	PTD. with barrier	16	CONCRETE	0
47	W	0	3	PTD. with barrier	16	CONCRETE	2
48	W	0	3	PTD. with barrier	16	CONCRETE	0
49	W	0	3	PTD. with barrier	16	CONCRETE	2
50	W	0	4	Grass	40	CONCRETE	0
51	W	0	4	Grass	40	CONCRETE	0
52	W	0	4	Grass	40	CONCRETE	1
53	W	5730	3	Grass	40	CONCRETE	2
54	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
55	W	17189	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
56	W	0	4	LAWN & GU.RAIL	40	HIGH ASPHALT	0
57	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	2
58	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
59	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
60	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1
61	W	0	3	Grass	128	HIGH ASPHALT	2
62	W	5730	3	LAWN & GU.RAIL	40	HIGH ASPHALT	1

Loop	Direction	Radius	Lanes	Median Type	Median Width	Type Of Pavment	Number Of Number of ramps At Loop
63	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
64	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
65	W	0	3	LAWN & GU.RAIL	40	HIGH ASPHALT	0
66	W	0	3	Grass	64	HIGH ASPHALT	0
67	W	0	3	Grass	64	HIGH ASPHALT	0
68	W	0	3	Grass	64	HIGH ASPHALT	0
69	W	0	3	Grass	64	HIGH ASPHALT	1
70	W	0	2	Grass	64	HIGH ASPHALT	1
71	W	0	2	Grass	64	HIGH ASPHALT	1

Date:	Contract ID:	Financial Project ID:	Inspector:

High Temp:	AM Conditions:	PM Conditions:
Low Temp:		

Remarks			
General:			
Accidents: ☐No ☐Yes See Accident Report Dated:	Day of Week:	Contract Day:	Total Days:
Visitors:			

Contractor(s) and Personnel										
#	Name	Type	#	Hrs	Type	#	Hrs	Type	#	Hrs
1.	Prime	Supt			Foreman			Skilled		
		Semi skilled			Common			Trainee		
2.	Sub/Utility	Supt			Foreman			Skilled		
		Semi skilled			Common			Trainee		
3.	Sub/Utility	Supt			Foreman			Skilled		
		Semi skilled			Common			Trainee		
4.	Sub/Utility	Supt			Foreman			Skilled		
		Semi skilled			Common			Trainee		

Contractor(s) Equipment (Active or Idle)					
Contr/Sub #	Equipment ID	Description	# Pieces	# Used	Total Hours Used

Date:	Contract ID:

Estimated Work Performed							
Contr/ Sub #	Line Item #	Pay Item Code	Location	Time (AM/PM)		Installed	
				Beginning	Ending	Qty.	Units

EFFECTS OF WEATHER ON MAJOR WORK ITEMS (CHECK CONTROLLING ITEMS):

Major and/or Controlling Work Items	No Effect All Day	Affected Less Than 50% of Work Day	Affected More Than 50% Of Work Day	No Work All Day
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐
	☐	☐	☐	☐

CONTRACTOR PAST PERFORMANCE
PURSUIT OF THE WORK: ☐ YES ☐ NO
CONFORMANCE WITH CONTRACT DOCUMENTS: ☐ YES ☐ NO

TECHNICIAN'S SIGNATURE AND RATING:	HOURS AT JOB SITE		TOTAL HOURS
	FROM:	TO:	

ENGINEER IN CHARGE (NAME, RANK AND INITIALS):	
	DATE:

Figure A–1 Sample Of Daily Construction Report Used To Collect Data

APPENDIX B LOOP STATION LOCATIONS

Table B-1 List of loop stations and locations

LOOP	MILE POST (E)	MILE POST (W)	LOCATION
	7.885	7.885	Osceola–Orange County line
7	0.405	0.405	Nearby ramps for 536
8	1.081	1.043	w of SR 536 overpass
9	1.668	1.679	e of eb 536 ramps
10	2.293	2.293	w of 535 ramps
11	2.861	2.861	e of 535 ramps
12	3.467	3.467	.5 mi e of 535
13	4.242	4.242	1 mi e of 535
14	4.814	4.814	w of Central Fla Pkway ramp
15	5.378	5.378	at Central Fla Pkway bridge
16	5.929	5.929	w of SR 528 ramps
17	6.564	6.564	e of SR 528 ramps
18	7.132	7.132	Approx 1 mi w of SR 528
19	7.672	7.672	Approx 1 mi w of SR 482
20	8.164	8.164	w of SR 482 ramps
21	8.751	8.751	e of eb SR 482 ramps
22	9.244	9.244	e of wb I–4 off ramp to SR 482
23	9.797	9.812	e of universal blvd overpass
24	10.380	10.342	SR 435 (Kirkman Road) Bridge
25	10.778	10.778	w of Turnpike
26	11.327	11.327	e of Turnpike
27	11.821	11.821	e of ramps for Conroy Road by Shingle Creek Bridge
28	12.369	12.369	Conroy Road Bridge
29	12.918	12.918	e of Conroy Road
30	13.638	13.638	w of John Young Parkway (SR 423)
31	14.149	14.149	e of SR 423
32	14.679	14.679	e of US 441 (Orange Blossom Trail)
33	15.030	15.030	US 441 Bridge
34	15.569	15.569	Michigan St bridge
35	16.024	16.024	Kaley Bridge
36	16.535	16.535	Pedestrian Overpass
37	17.047	17.047	w of SR 408 (East West Expressway)
38	17.397	17.397	e of SR 408
39	17.440	17.440	Church Street Bridge
40	17.908	17.908	Livingston Street Bridge
41	18.439	18.439	SR 50 bridge
42	18.912	18.912	e of Ivanhoe bridge
43	19.433	19.433	w of Princeton St
44	19.925	19.925	e of Princeton St
45	20.423	20.423	Par St
46	20.995	20.995	Formosa/Minnesota Bridges
47	21.403	21.403	Fairbanks Bridge
LOOP	MILE	MILE	LOCATION

	POST (E)	POST (W)	
48	21.838	21.838	e of Wymore Bridge
49	22.340	22.340	Lee Road Bridge
50	22.747	22.747	e of Lee Road ramps
51	23.202	23.202	Eatonville Road bridge
52	23.751	23.751	w of SR 414 (Maitland Blvd)
53	24.187	24.187	SR 414 bridge
	24.673	24.673	e of SR 414 ramps, Orange–Seminole county line
54	0.025	0.025	Douglas Ave/ Wymore Road Bridge
55	0.570	0.570	e of Douglas Ave/ Wymore Bridge
56	1.105	1.105	w of SR 436 (Semoran Blvd)
57	1.569	1.569	e of SR 436 ramps
58	2.317	2.317	e of Central Pkwy
59	2.828	2.828	w of SR 434 ramps
60	3.425	3.425	SR 434 bridge
61	4.140	4.140	e of SR 434 ramps

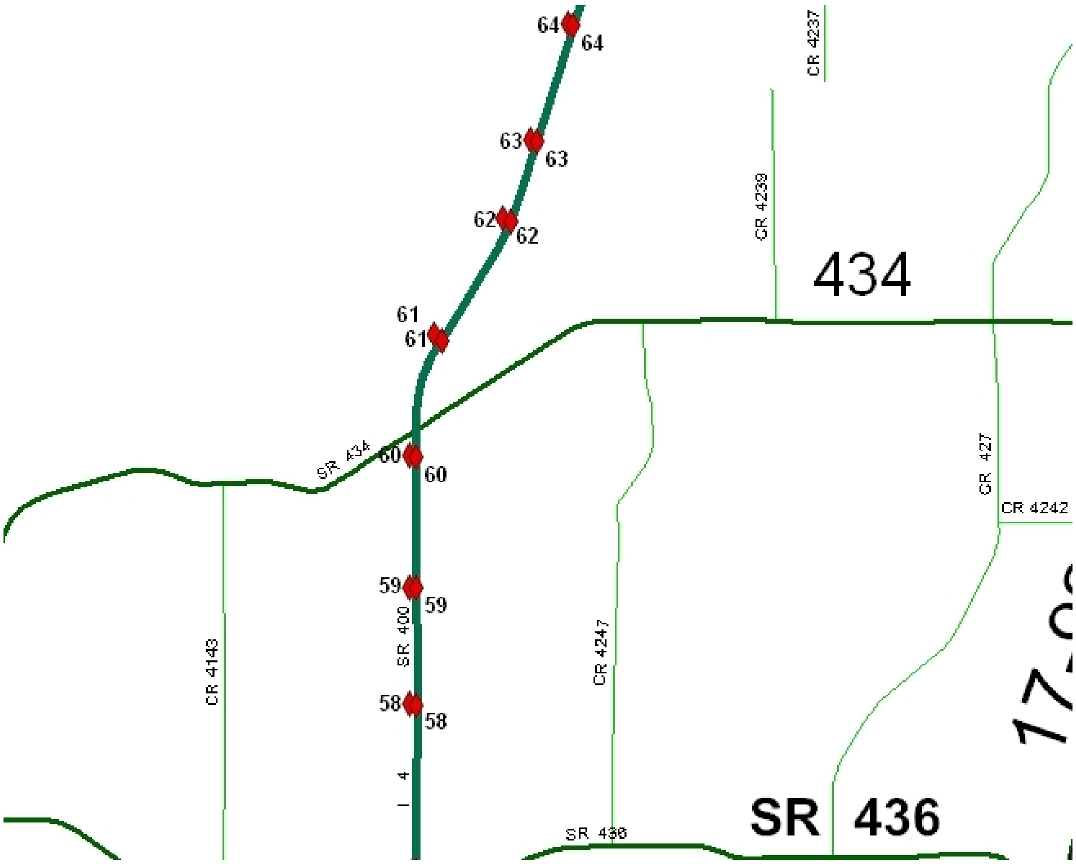

Figure B-1 Loop Location to scale SR 434 to SR436

Source: FDOT (2006), Orlando, Florida

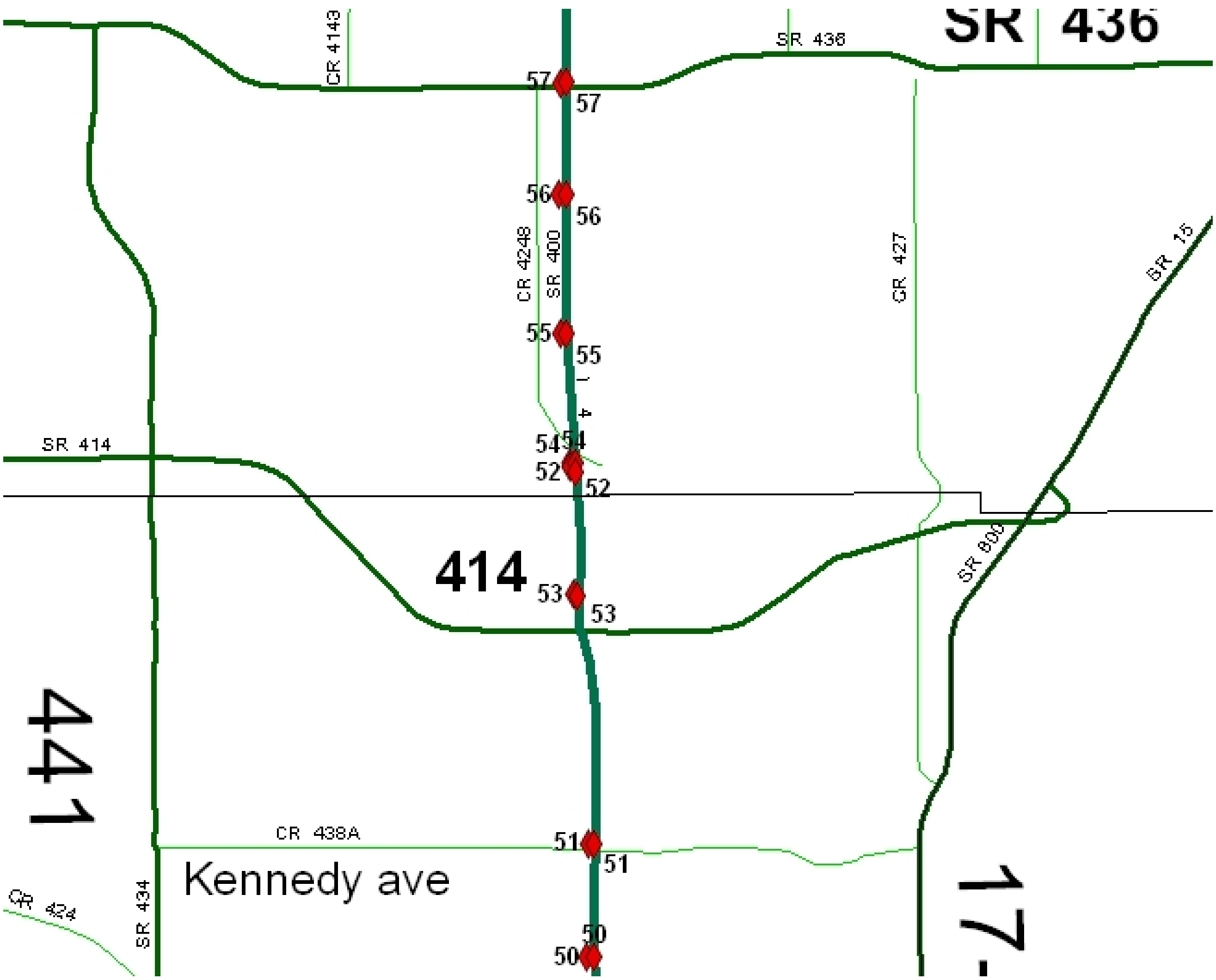

Figure B-2 Loop location from SR 436 to north of SR 423

Source: FDOT (2006), Orlando, Florida

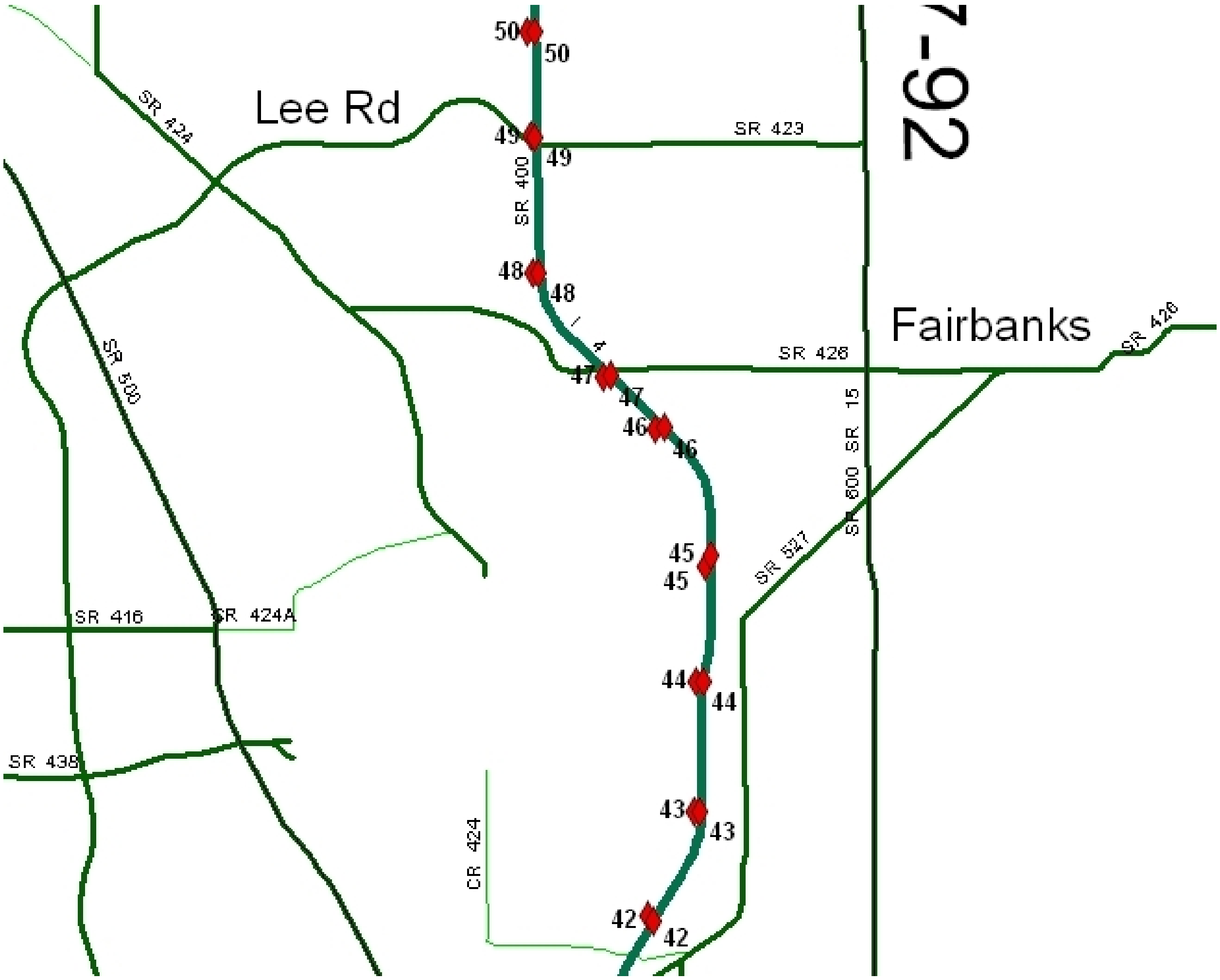

Figure B-3 Loop locations from SR 423 to south of SR 42

Source: FDOT (2006), Orlando, Florida

Figure B-4 Loop location from south (west) of SR 426 to SR 500

Source: FDOT (2006), Orlando, Florida

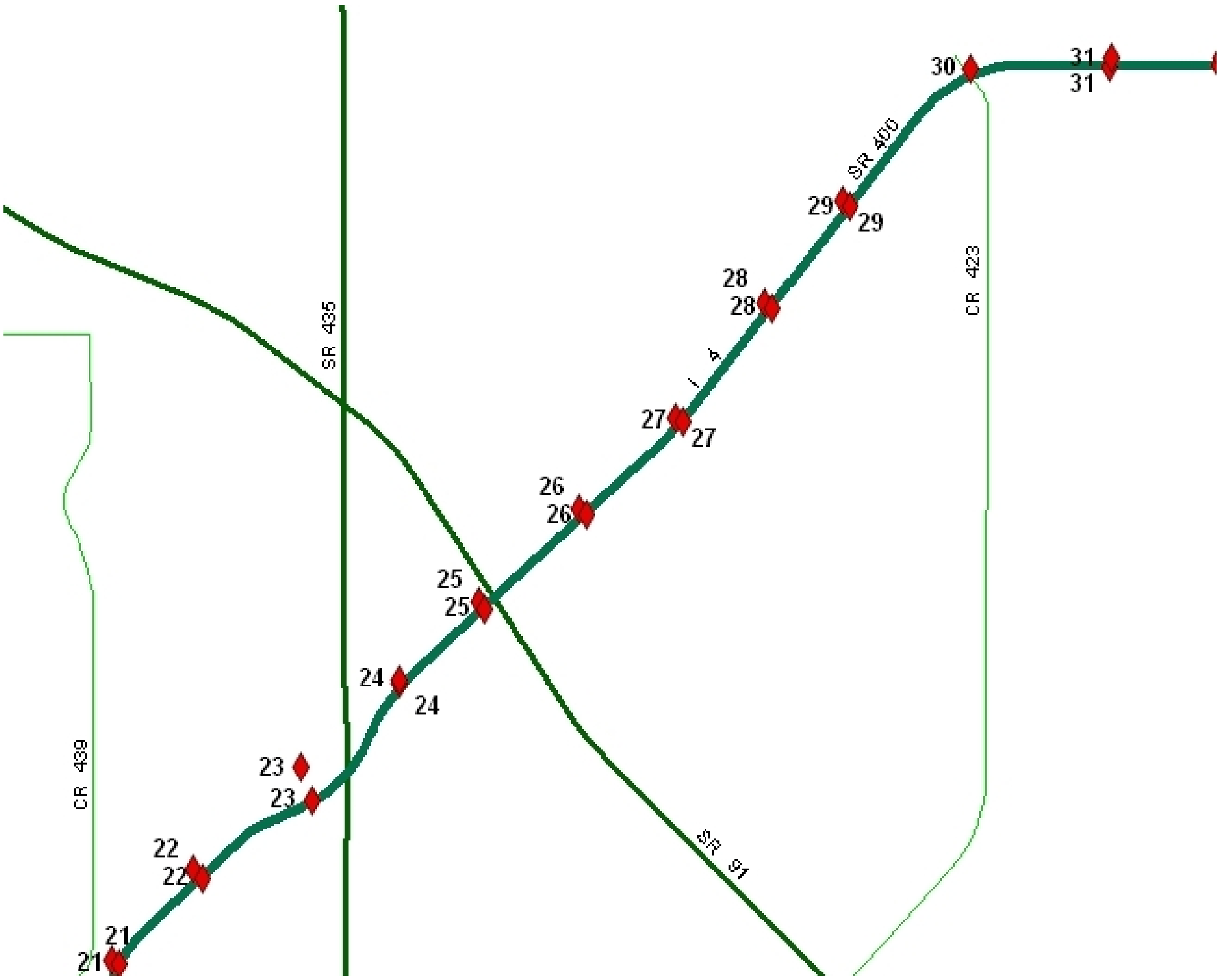

Figure B-5 Loop location from south (west) of SR 500 to south (west) of SR 91

Source: FDOT (2006), Orlando, Florida

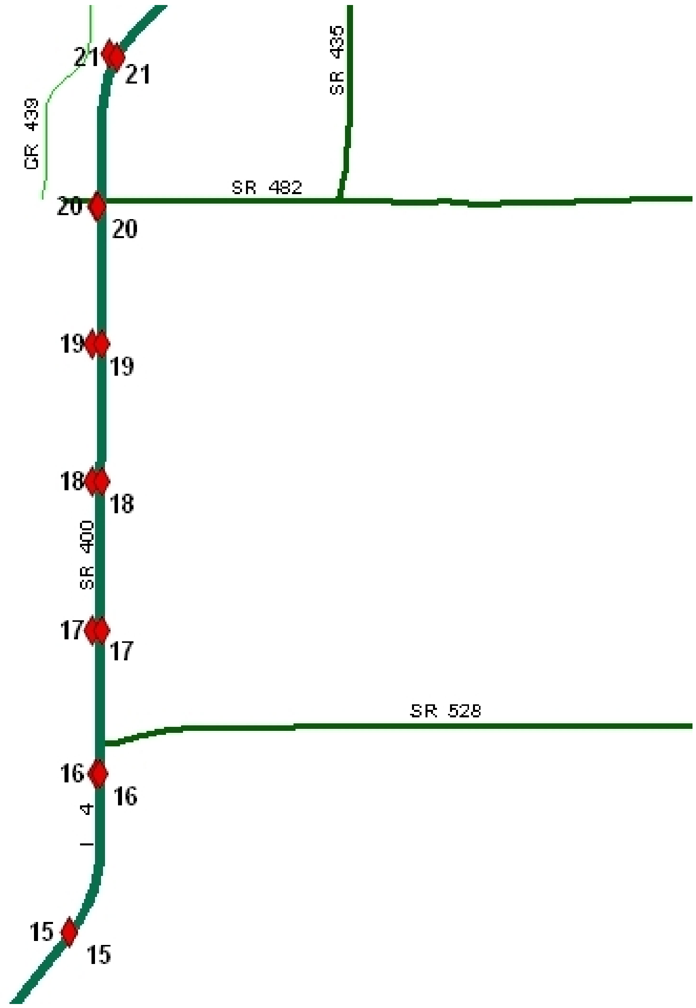

Figure B-6 Loop location from south(west) of SR 91 to south (west) of SR 528

Source: FDOT (2006), Orlando, Florida

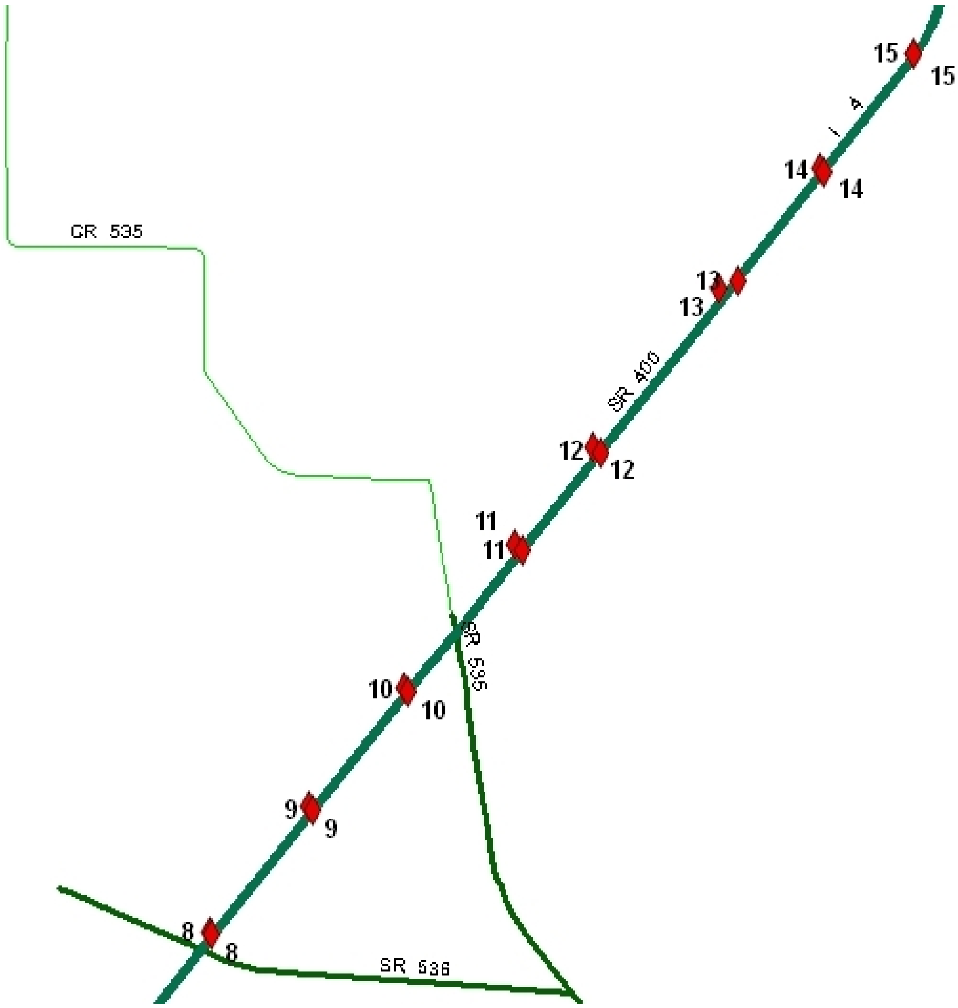

Figure B-7 Loop location from south(west) of SR 528 to SR 536

Source: FDOT (2006), Orlando, Florida

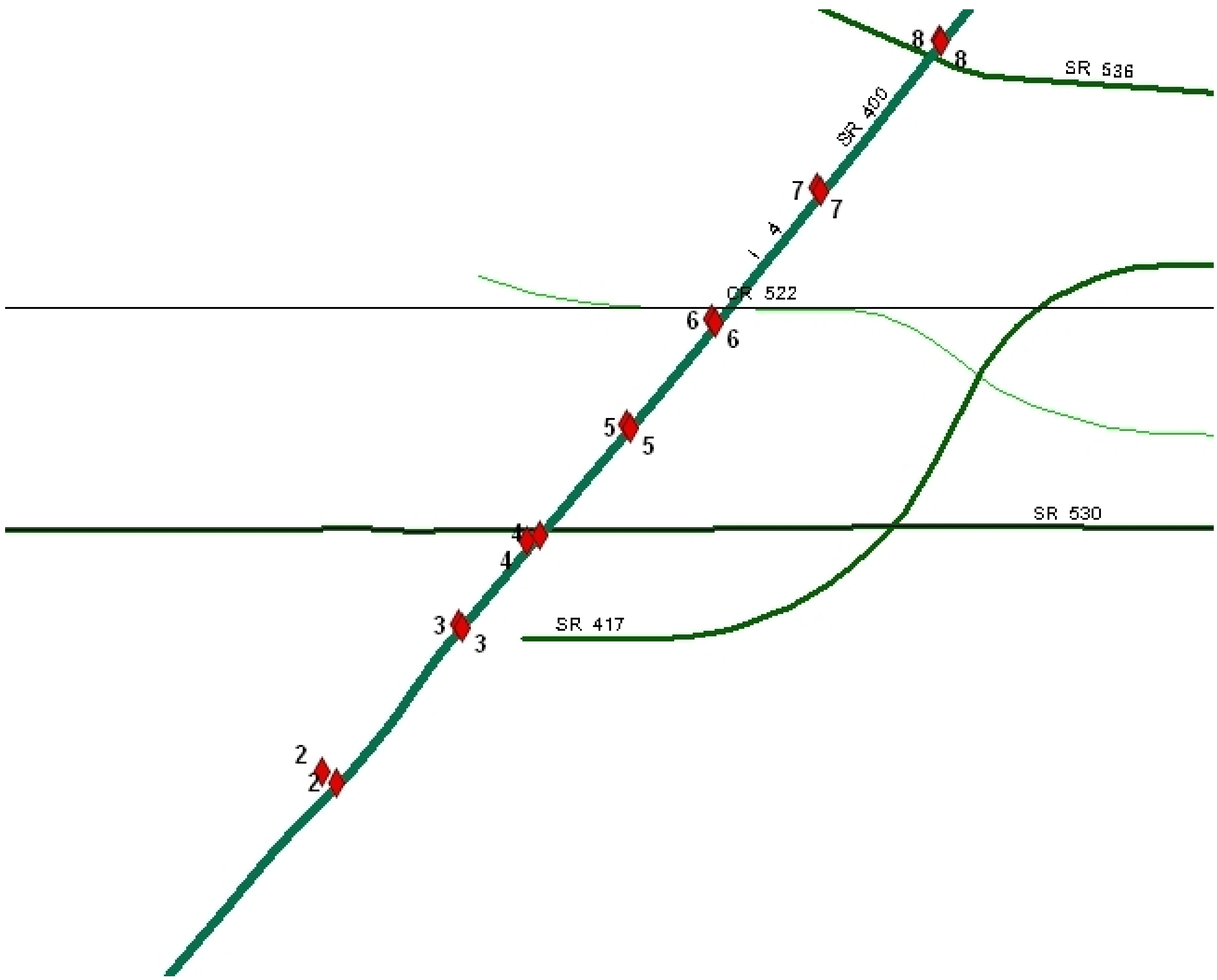

Figure B-8 Loop location from south of 536 to south(west) of 530

Source: FDOT (2006), Orlando, Florida

APPENDIX C PHOTOS OF THE PROJECTS

Figure C-1 Project 3 Bridgework

Source: FDOT (2006), Orlando, Florida

Figure C-2 Project 3 Base preparation

Source: FDOT (2006), Orlando, Florida

Figure C-3 Project 3 Base work

Source: FDOT (2006), Orlando, Florida

Figure C-4 Project 3 Median concrete and asphalt work

Source: FDOT (2006), Orlando, Florida

Figure C-5 Project 3 Bridge widening

Source: FDOT (2006), Orlando, Florida

Figure C-6 Project 3 Pond excavation

Source: FDOT (2006), Orlando, Florida

Figure C-7 Project 3 Bridge work

Source: FDOT (2006), Orlando, Florida

Figure C-8 Project 3 Bridge widening and pond excavation

Source: FDOT (2006), Orlando, Florida

Figure C-9 Project 2 Roadway widening and drainage work

Source: FDOT (2006), Orlando, Florida

Figure C-10 Project 2 Base work

Source: FDOT (2006), Orlando, Florida

Figure C-11 Project 2 Stabilization and limerock base

Source: FDOT (2006), Orlando, Florida

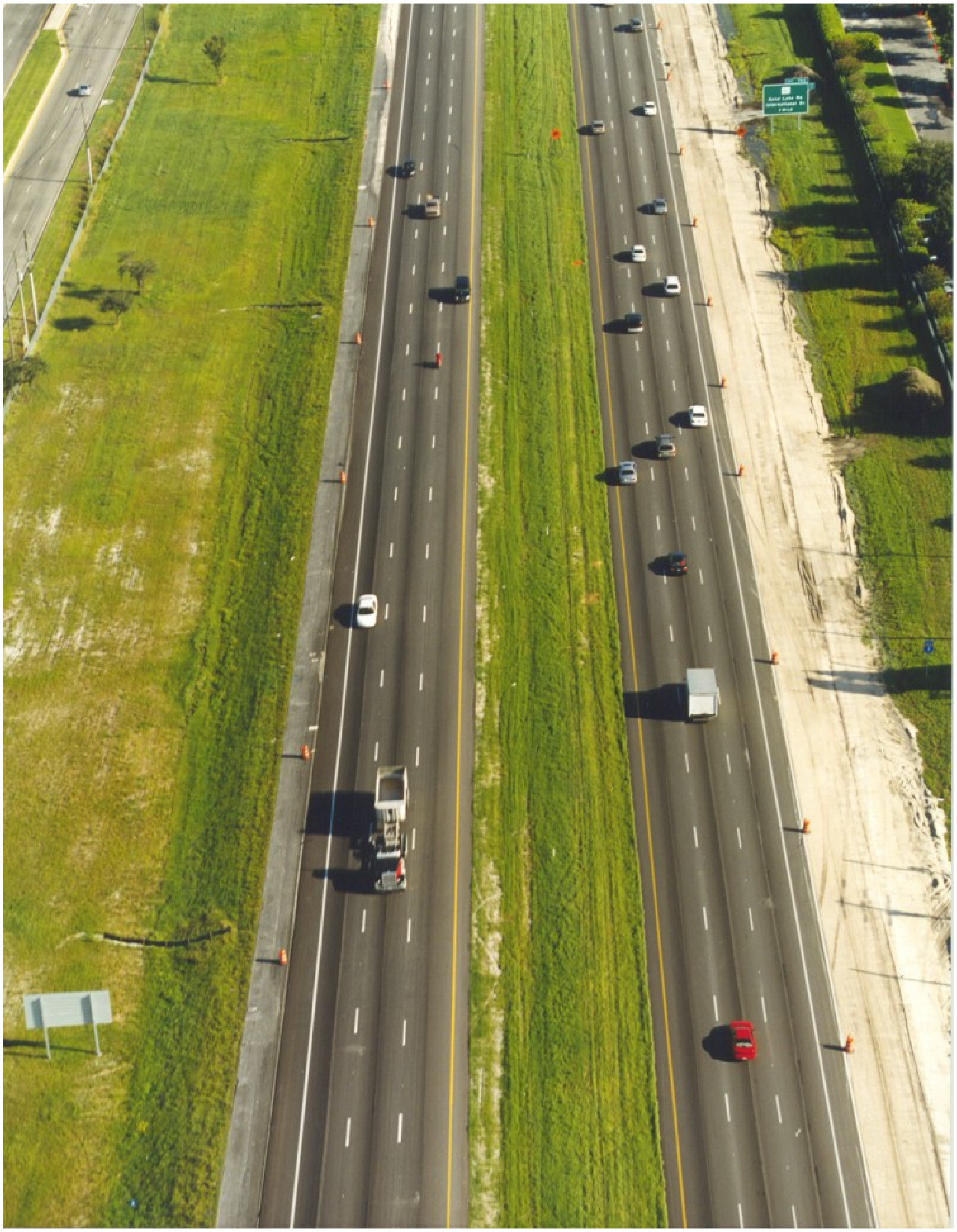

Figure C-12 Project 2 Stabilization and limerock base

Source: FDOT (2006), Orlando, Florida

Figure C-13 Project 2 Roadway widening complete

Source: FDOT (2006), Orlando, Florida

Figure C-14 Project 1 Roadway widening and bridgework

Source: FDOT (2006), Orlando, Florida

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